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A SURVEY OF IONOSPHERIC MODELS A PRELIMINARY REPORT ON THE DEVE--ETC(U)
JUL 82 J M GOODMAN, E O HULBURT
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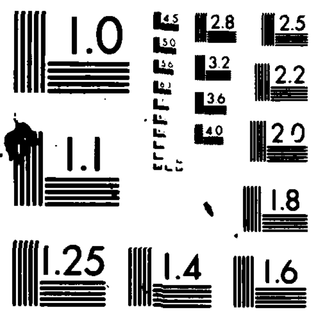

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Ionospheric effects	Forecasting
Radiowave propagation	Assessment

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This manuscript constitutes an interim progress report on an effort begun in early 1981 to compile a thesaurus and users guide for various ionospheric models which are used to assist in analysis of the radiowave propagation medium. The current status of the effort is given and future plans are outlined.

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A SURVEY OF IONOSPHERIC MODELS
A PRELIMINARY REPORT ON THE DEVELOPMENT OF AN IONOSPHERIC MODEL THESAURUS AND USERS GUIDE

1.0 Introduction

Ionospheric models of various categories have been developed for several decades with the greatest advances being made since the advent of the space age. The earliest models were developed to synopsize empirical data and/or to gather insight vis-a-vis the underlying physical and chemical processes operating in the atmosphere. These efforts have added considerably to our knowledge of the entire hierarchy of solar-terrestrial relationships and basic research programs of this category are still continuing. The quest for basic knowledge still exists but more current interest in modeling is directed toward the development of models which may be utilized by designers and operators of radiowave propagation systems. In the current DoD vernacular the contraction "C^3I system" is employed. This term refers to Command, Control, Communication and Intelligence systems. In actuality C^3I, a military term, may be used to describe a wide range of disparate applications. However, for the purpose of this report, the military application is emphasized. C^3I is in actuality "the centralization and coordination of sets of various resources which are physically remote from the center, using all the required techniques available" [Morris, 1977]. In all C^3I systems, including the military, there is the principal requirement of centralized coordination and amalgamation of resources and sensors which may be distributed over large global distances. This definition is particularly valid for the military which maintains that C^3I is an effective "force multiplier". This can only be the case if the C^3I systems enables more efficient operation, improved accuracy, greater speed, and higher reliability. It is important to recognize that communication - which may be regarded as the first "C" of C^3I - is the "glue" which holds the whole system together. Even though other elements of the C^3I family may use radio links to access or extract "data" or surveillance information, the fusion of all assets is accommodated only through reliable, timely and error-free connectivity. There are a number of radio systems currently employed to provide the "glue" for C^3I. Other radio systems are central to specialized functions such as EAM (or Emergency Action Messages) and others may be principally utilized for specific surveillance functions. As the technology for C^3I systems became more advanced through incorporation of modern computers, the most vulnerable part of the C^3I system becomes that component which is least susceptible to control, the ionospheric/atmospheric channel.

The ionosphere, or more generally the geoplasma medium incorporating the free electrons which reside in the so-called exoatmosphere above 50 km in altitude, is probably the most obvious - if not the major - component of the total propagation channel. The troposphere is the other component. For radio frequencies between the Ultra Low (ULF) and the Super High (SHF), the ionosphere is the major medium of influence. At the Extremely High (EHF) or microwave frequencies, the troposphere becomes dominant. It is remarked that this statement must be modified for high zenith angles for which tropospheric ducting and refraction effects become important in the higher VHF and UHF bands. A discussion of this bifurcation in dominance is discussed in terms of system effects by Goodman [1980,1981] and Goodman and Aarons [1981].

Morris D.J., 1977, Introduction to Communication, Command and Control Systems, Pergamon Press, Elmsford, N.Y. 10523, USA.

Manuscript submitted March 18, 1982.

The purpose of this report is to outline the progress of an on-going NRL project to compile information pertinent to existing ionospheric and ionospherically sensitive radiowave propagation models. The total effort is supported in part through ongoing basic research programs but is principally directed toward applied research goals for support of HF and satellite communication/surveillance systems. The motivation for the study is derived from the author's affilation with the Electromagnetic Wave Propagation Panel (EPP) of the Advisory Group for Aerospace Research and Development (AGARD) under the aegis of the North Atlantic Treaty Organization (NATO). The NATO/AGARD official interest is in the development of an "Ionospheric Model Thesaurus and Users Guide". This report constitutes the first step in that development.

2.0 Scope of the Study

There are, of course, a myriad of ionospheric models as well as radiowave propagation models which have been developed over the years. The first phase of the study undertaken in development of the "Ionospheric Model Thesaurus and Users Guide" is to identify the most current active models. In order to accomplish this task it was necessary to undertake a comprehensive literature search to obtain a data base. A set of references has been developed as a result of this search and this listing is attached as Appendix A. At this time the bibliography is incomplete and work is continuing. Another approach, and the principal subject of this memoradum, is to obtain the necessary information more directly, either through questionaires or interviews. Two questionaires have been developed for this purpose and they have been forwarded to the "ionospheric constituency". The mailing list included the following groups: Attendees at the 1975, 1978, and 1981 IES conferences, attendees at recent NATO/AGARD conferences, and selected individuals in the IEEE, AGU, and URSI standard mailing lists. Appendix B contains blank versions of the questionaires which were forwarded to individuals and/or organizations on the mailing list. The scope of the effort outlined in this manuscript is basically limited to reporting the results of the questionaires. However, a brief synopsis of current activities related to ionospheric prediction, mapping, and assessment, as well as propagation model development are included. The discussion concludes with a brief outline of future plans in connection with preparation of an AGARDOGRAPH.

3.0 Statistics Associated with Questionaire Responses

Thirty-eight (38) individuals from twenty-five (25) different organizations responded to the questionaire as of this writing. These individuals, who were not necessarily the custodians of code, primarily regarded themselves as developers (D) of models by a large margin. The following breakdown was found:

Goodman J.M., 1980, "Environmental Constraints in Earth-Space Propagation", NRL Memorandum Report 4339, Washington, D.C. [Also presented at NATO-AGARD Conference May 1980 (London)].

Goodman J.M., 1981, "The Environment and Earth-Space Propagation - Challenges for the Future" in Naval Research Reviews (Winter/Spring edition).

Goodman J.M. and J. Aarons, 1981, "The Radiowave Propagation Environment - Science and Technology Objectives for the 80's" in Effect of the Ionosphere on Radiowave Systems, J.M. Goodman, (editor-in-chief) U.S. Gov't Printing Office, Washington, D.C.

TABLE I

	Responses	Developers	Exclusively Developers	Users	Exclusively Users	Users & Developers
No.	38	31	26	12	7	5
%	100	81	68	31	18	13

No editing of the respondee identification of him (her)-self as either a developer or a user was attempted. Although such editing is tempting, it was avoided to allow for the identification of a perception problem in the domain of the user-customer relationship. Some regard the ultimate user as, for example, the "white hat" in the Fleet who must use equipment which is dependent upon the ionospheric channel, a medium he knows little about. In this instance all echelons above this "ultimate" user are either developers or designers. Others, specifically scientists who regard themselves as developers, view the sponsor/funding agency as the customer/user which is usually an erroneous view if we are defining model utility strictly in terms of its specific impact on system development or operation. If the intent of model development is to advance one's knowledge of the ionosphere, however, the user may be simply the scientific community at large. In this instance a scientist may regard himself as a user of models or perhaps even both. Thus, a misinterpretation of the terms "user" suggests that we should consider the following bifurcation of terms: the scientific-user and the systems-user. Typically the systems-user is implied when referring to the term "user" alone.

There are also users of "long-term" models and another category of users for which model development and application is of more immediate concern. The former category contains system designers as well as architects who are responsible for an a-priori evaluation of system performance. This responsibility includes definition of the degree of system robustness required; i.e., the margins over which systems must be designed to adapt. In the latter category we include the ultimate user in the operational arena in addition to those managers who are in need of immediate band-aid fixes for inadequately designed systems. Inadequacy of design is, of course, not always a result of the non-recognition of potential problems which have been identified in R&D efforts many years before, although it may be. It is sometimes a result of a changing operational environment which necessitates greater system performance than previously envisioned. More often than not it is directly related to the perceived threat within a specified warfare area. Unfortunately these perceptions change from time-to-time. Because the environment of the ultimate user is so dynamic, user requirements usually have a short-fuse and this necessitates a flexibility of response by the R&D community. This argues for a broadly-based R&D program to achieve this goal. In the area of ionospheric research, or more specifically model development, this is no less true.

4.0 Listings of Respondees

Tables II and III below are alphabetical listings of organizations and individuals, respectively, which/who responded to the questionaires.

TABLE II

ORGANIZATIONAL RESPONSE TO QUESTIONAIRES

ORGANIZATION	ADDRESS
1. AIR FORCE GEOPHYSICS LABORATORY	L. G. Hanscom AFB Massachussets 01731, USA
2. AIR FORCE WEAPONS LABORATORY	Wright Patterson AFB Ohio 45433, USA
3. APPLIED PHYSICS LABORATORY	Johns-Hopkins University Johns-Hopkins Road Laurel, Maryland 20707, USA
4. APPLIED RESEARCH LABORATORY	University of Texas at Austin P.O. Box 8029, 10000 Burnet Rd. Austin, Texas 78712, USA
5. CENTRE FOR RADIO SCIENCE	University of Western Ontario London, Ontario, Canada
6. COMMUNICATIONS SATELLITE CORPORATION	COMSAT Laboratories Clarkesburg, Maryland, 20734 USA
7. EMMANUEL COLLEGE	400 The Fenway Boston, Massachussets 02115 USA
8. ENVIRONMENTAL RESEARCH LABORATORIES	National Oceanic and Atmospheric Administration U.S. Dept of Commerce Boulder, Colorado 80303, USA
9. FORSCHUNGSINSTITUT FUR HOCHFREQUENZPHYSIK (FGAN)	Konigstrasse 2 D-5307 Wachtberg-Werthhaven FRG
10. GEOPHYSICAL INSTITUTE	University of Alaska 903 Koyukuk Ave. North Fairbanks, Alaska 99701 USA
11. INSTITUTE FOR TELECOMMUNICATION SCIENCE	U.S. Dept of Commerce NTIA/ITS, 3413-1 325 South Broadway Boulder, Colorado 80303, USA
12. LOS ALAMOS NATIONAL LABORATORY	Los Alamos, New Mexico 87545 USA

13. MITRE CORPORATION	Rt. 62 Bedford, Massachussets 01730 USA
14. NAVAL INTELLIGENCE SUPPORT CENTER	4301 Suitland Rd. Washington, D.C. 20390, USA
15. NAVAL RESEARCH LABORATORY	4555 Overlook Avenue Washington, D.C. 20375, USA
16. PHYSICAL DYNAMICS INC.	P. O. Box 3027 Bellevue, Washington 98009 USA
17. RCA GOVERNMENT & COMMERCIAL SYSTEMS	Astro-Electronic Division P. O. Box 800 Princeton, New Jersey 08540 USA
18. RICE UNIVERSITY	Weiss School of Natural Sciences P.O. Box 1892 Houston, Texas 77001, USA
19. SIGNATRON	12 Hartwell Avenue Lexington, Mass. 02173 USA
20. SPACE ENVIRONMENT LABORATORIES (SEL)	National Oceanic and Atmospheric Administration U.S. Dept of Commerce 325 South Broadway Boulder, Colorado 80303, USA
21. SOUTHWEST RESEARCH INSTITUTE	P.O. Drawer 28510 6220 Culebra Road San Antonio, Texas 78284, USA
22. STANFORD RESEARCH INSTITUTE INTERNATIONAL	333 Ravenswood Avenue Menlo Park, California 94025 USA
23. UNIV. OF CALIFORNIA AT SAN DIEGO	Dept. of E.E. & Computer Sci. Mail Code C-014 La Jolla, California 92093 USA
24. U.S. ARMY COMM-ELECTRONICS ENGINEERING INSTALLATION AGENCY	Attn: CCC-EMEO Ft. Huachuca, Arizona 85613 USA
25. UTAH STATE UNIVERSITY	Physics Department Logan, Utah 84322, USA

TABLE III

ALPHABETICAL LISTING OF RESPONDEES TO QUESTIONAIRES

1.	AARONS, Jules, Dr.	Boston University Department of Astronomy 705 Commonwealth Ave. Boston, MA 02215 Phone: 617-353-2639 DEVELOPER X USER _
2.	ALBRECHT, Hans J., Dr.	FGAN, Konigstr. 2 5307 Wachtberg FRG DEVELOPER X USER _
3.	AMES, John W., Dr.	SRI International, 333 Ravenwood Ave. Menlo Park, CA 94025, USA Phone: (415) 859-3662 TELEX: 910-373-1246 DEVELOPER X USER _
4.	ANDERSON, David N., Mr.	NOAA/ERL/SEL U.S. Dept of Commerce Boulder, CO 80302, USA Phone: (303) 497-5327 DEVELOPER X USER _
5.	BASU, Sunanda, Dr. (Also Dr. Santimay Basu)	Emmanuel College 400 the Fenway Boston, MA 02115, USA Phone: (617) 861-3974 DEVELOPER X USER _
6.	BEARCE, Loren S., Mr.	Code 7586 Naval Research Laboratory 4555 Overlook Ave., Washington, D.C. 20375, USA Phone: (202) 767-2400 DEVELOPER _ USER X
7.	BRAMEL, Edwin F., Mr.	Commander U.S. Army Comm-Electronics Eng. Installation Agency, ATTN: CCC-EMEO Ft. Huachuca, AZ 85613, USA Phone: (AUTOVON) 879-6779 (FTS) 761-2151 Ext. 6779 (Com) (602) 538-6779 DEVELOPER X USER X
8.	CHRISTOPHER, Paul, Mr.	Mitre Corporation Rt. 62 Bedford, MA 01730, USA Phone: (617) 271-3540 DEVELOPER X USER _

9. CLYNCH, James R., Dr.

Applied Research Laboratory
University of Texas at Austin
P.O. Box 8029, 10,000 Burnet Road
Austin, TX 78712, USA
Phone: (512) 835-3380
DEVELOPER X USER _

10. FANG, Dickson J., Dr.

COMSAT Labs, Communication Satellite Corp.
22300 Comsat Drive
Clarkesburg, MD 20871, USA
Phone: (301) 428-4131
TELEX: 8966
DEVELOPER X USER _

11. FREMOUW, Edward J., Dr.

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P.O. Box 3027
Bellevue, WA 98009, USA
Phone: (206) 453-8141
DEVELOPER X USER _

12. GANGULY, Suman, Dr.

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Rice University 6100 S. Main
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Houston, TX 77001, USA
Phone: (415) 859-3318
DEVELOPER X USER _

13. HATFIELD, V. Elaine, Mrs.

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Menlo Park, CA 94025, USA
Phone: (415) 859-3318
DEVELOPER X USER _

14. HAYDEN, Edgar C., Dr.

Southwest Research Institute
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San Antonio, TX 78284, USA
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TELEX: 767357
DEVELOPER X USER X

15. HESSING, Anne R., Ms

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333 Ravenswood Ave.
Menlo Park, CA 94025, USA
Phone: (415) 859-3618
TELEX: 910-373-1246
DEVELOPER X USER _

16. HORAN, Donald M., Dr.

Code 4175H, Naval Research Laboratory
4555 Overlook Avenue, S. W.
Washington, D. C. 20375, USA
Phone: (202) 767-2350
DEVELOPER X USER _

17. JOHNSON, Allen L., Mr.

AFWAL/AAAD Wright Patterson AFB
Ohio 45433, USA
Phone: (513) 255-2697
DEVELOPER _ USER X

18. JONES, R. Michael, Dr. — NOAA Wave Propagation Laboratory
U.S. Dept of Commerce
Boulder, CO 80303, USA
Phone: (303) 497-6464
DEVELOPER X USER _

19. KELLEY, Edward J., Mr. — Project Manager, Environmental Sciences
Naval Intelligence Support Center
4301 Suitland Road
Washington, D.C. 20390, USA
Phone: (202) 763-1635
DEVELOPER _ USER X

20. LANE, George, Mr. — USACEEIA, ATTN: CCC-EMEO-PED
Ft. Huachuca, AZ 85613, USA
Phone: (602) 538-6779
DEVELOPER X USER _

21. LLOYD, John L., Mr. — U.S. Dept of Commerce NTIA/ITS 3413-1
325 South Broadway
Boulder, CO 80303, USA
Phones: (COM) (303) 497-3701 or 3813
(FTS) 320-3701
DEVELOPER X USER _

22. MAC DOUGALL, John W. (Prof) — Centre for Radio Science
University of Western Ontario
London, Ontario, NCA 3K7, CANADA
Phone: (519) 679-6294
DEVELOPER X USER X

23. MALAGA, Alfonso, Dr. — Signatron
12 Hartwell Ave.
Lexington, MA 02173, USA
Phone: (617) 861-1500
DEVELOPER X USER _

24. MATHWICH, H.R., Mr. — Staff System Scientist
RCA Gov't and Commercial Systems
Astro-Electronics Division
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Princeton, N.J. 08540, USA
Phone: (609) 448-3400
DEVELOPER _ USER X

25. MOSER, Philip J., Mr. — Code 7009 Concept Development Staff
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4555 Overlook Ave., S.W.
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DEVELOPER _ USER X

26. PAUL, Adolf K., Dr. — NOAA-SEL
R43 325 S. Broadway
Boulder, CO 80303, USA
Phone: (303) 497-3432
DEVELOPER X USER _

27. PHILBRICK, Charles R., Dr. Air Force Geophysics Laboratory
AFGL/LKB
Hanscom AFB, MA 01731, USA
Phone: (617) 861-4944
TELEX: 309-23427
DEVELOPER X USER _

28. PONGRATZ, Morris B., Dr. Project Leader MS 466
Los Alamos National Laboratory
Los Alamos, N.M. 87545, USA
Phone: (505) 667-4740
DEVELOPER _ USER X

29. RICH, Frederick J., Dr. Air Force Geophysics Laboratory
Hanscom AFB, MA 01731, USA
Phone: (617) 861-2431
DEVELOPER X USER _

30. SAGALYN, Rita C., Mrs. Air Force Geophysics Laboratory
Hanscom AFB, MA 01731, USA
Phone: (617) 861-2431
DEVELOPER X USER X

31. SCHUNK, Robert W., Prof. Utah State University
Physics Dept.
Logan, UT 84322, USA
Phone: (801) 750-2974
DEVELOPER X USER _

32. SUGAI, Iwao, Dr. Applied Physics Laboratory
Johns Hopkins University
Johns Hopkins Road
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DEVELOPER X USER X

33. SZUSZCZEWICZ, Edward, P. Dr. Code 4187, Naval Research Laboratory
4555 Overlook Ave., S.W.
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DEVELOPER X USER _

34. THOMASON, Joseph F., Mr. Code 5324T, Naval Research Laboratory
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35. VATS, Hari Om, Dr. Electrical Engineering and Computer Sciences
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DEVELOPER X USER _

36. WATKINS, Brenton J., Dr. Geophysical Institute, University of Alaska
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North Fairbanks, Alaska 99701, USA
Phone: (907) 479-7479
DEVELOPER X USER _

37. ZANETTI, Lawrence J., Dr. Research Ass't S.I.P.
Applied Physics Laboratory
Johns Hopkins University
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Laurel, MD 20810, USA
Phone: (301) 953-7100
DEVELOPER _ USER X

38. ZINN, John, Dr. Los Alamos National Laboratory
P.O. Box 1663
Los Alamos, N.M. 87545, USA
Phone: (505) 667-6403
DEVELOPER X USER _

We note that thirty six (36) of the thirty eight (38) responses were from the U.S. with the foreign reponses being from Canada and FRG. Of the twenty five (25) organizations responding (some clearly with multiple respondees), the mix was almost equally divided between U.S. Government, University or University-affiliated laboratories/institutes, and industrial/other.

It is clear, and was certainly anticipated, that the response to the questionaires would be weighted toward the U.S. This is no doubt a natural consequence of the imbalance in the mailing list utilized. It is also noteworthy that greatest organization response came from NRL and AFGL. This is not necessarily related to activity in modelling development or use by these organizations but is probably a result of the fact that the author is affiliated with the former organization and there is historically a strong interest in NATO-AGARD activities by individuals in the later organization. Even so, the questionaire contributions by AFGL and NRL are certainly not complete from first-hand knowledge of work being conducted by these laboratories.

Obviously there are problems involved in applications of a questionaire approach to obtain information. One of these involves the "procrastination syndrome" which is handled best by direct contact or telephone. Another is related to the psychology of the questionaire approach itself with many individuals being biased against such an activity. Another is related to the "sampling algorithm" employed i.e., the mailing list. Steps have been undertaken to alleviate the "sampling" problem. This involves literature search, a time-consuming exercise at best.

5.0 Ionospheric Model Data from the Questionaires

Table IV below is an alphabetical listing of the Ionospheric/Propagation models identified from the returned questionaires. (In some instances, a short model name is used. In these cases the title is listed with quotation marks. The author of this report takes full responsibility for any inappropriateness.)

TABLE IV

List of Models Indicated in Questionaire Responses

	MODEL	RESPONDEE(S)	CUSTODIAN(S) (If other than respondee)
1.	"AFGL Scintillation Occurrence"	<u>Aarons</u>	
2.	"Albrecht Scintillation Model"	<u>Albrecht</u>	
3.	AMBCOM	<u>Hatfield</u>	
4.	ANTCAP/SETCOM	Bramel	Lloyd, NTIA/ITS
5.	ARL:UT	<u>Clynch</u>	
6.	ARMY Prophet (APES)	Lane	Rose, NOSC
7.	Auroral Dynamic Ionosphere	<u>MacDougall</u>	
8.	"Basu Scintillation Model"	<u>Basu and Basu</u>	
9.	DMSP Thermal Plasma Density	<u>Sagalyn</u>	
10.	Fangs Plot	<u>Fang</u>	
11.	F-Region Servo Model	<u>Ganguly</u>	
12.	"Indian Subcontinent Scintillation Model"	Vats	Desphande, PRL/India
13.	IONCAP	Bramel, <u>Lloyd</u>	Lloyd, Lucas Hayden, Teters NTIA/ITS
14.	IONOS	<u>Zinn</u>	Zinn, Sutherland, LANL
15.	IONO4	<u>Christopher</u>	Rogers, Christopher Mitre Corp.
16.	"Jones/Stephenson Ray Tracing Model"	<u>Jones</u>	Jones and Stephenson WPL/NOAA
17.	Low/Mid-Lat F Region Model	<u>Anderson</u>	
18.	NEC	Bramel	Burke
19.	NRL Ionospheric Model	<u>Thomason</u>	
20.	Polar/F	<u>Watkins</u>	
21.	RADARC	<u>Hessing, Ames</u>	
22.	SIMBAL	Sugai	Kaman-Tempo
23.	Spectral Components of foF2	<u>Paul</u>	
24.	S3 Empirical F-Region Model	<u>Philbrick</u>	
25.	S3-3 Electron Temperature	<u>Rich</u>	
26.	"Utah State Hi-Lat Ionospheric Model"	<u>Schunk</u>	Schunk, Sojka, Utah State U.
27.	WBMOD	<u>Fremouw</u>	
28.	WESCOM	Sugai	Kaman-Tempo
29.	Wideband-HF	<u>Malaga</u>	
30.	YTCHIU	<u>Hayden</u>	

In Table IV the respondee's name is underlined if he/she is identified to be the custodian as well. Otherwise the custodian is listed in column three (3). The affiliations of the respondees are given in Table III and are not repeated in Table IV.

Table V below is a breakdown of the models by category. We note that there are three (3) major groupings in terms of the volume of response. They are: HF propagation (8 responses), the Ionosphere (12 responses), and scintillation (7 responses).

TABLE V

Models Identified by Category

HF PROPAGATION

AMBCOM
ANTCAP/SETCOM
ARMY PROPHET
IONCAP
JONES/STEPHENSON RAY TRACING
NRL IONOSPHERIC MODEL
RADARC
WIDEBAND HF

IONOSPHERE

ARL:UT
AURORAL DYNAMIC IONOSPHERE
DMSP THERMAL PLASMA DENSITY
F REGION SERVO
IONOS
LOW/MID-LAT F-REGION
POLAR F
SPECTAL COMPONENTS OF foF2
S3 EMPIRICAL F-REGION
S3 ELECTRON TEMPERATURE
UTAH STATE HI-LAT
YTCHIU

SCINTILLATION

ALBRECHT
AFGL SCINTILLATION OCCURRENCE
BASU
FANGS PLOT
INDIAN SUB-CONTINENT
IONO4
WBMOD

NUCLEAR EFFECTS

SIMBALL
WESCOM

OTHER

NEC

Upon inspection of Table V, it is clear to any worker in the field (of Ionospheric physics) that there are many other models which are not listed. In addition there are numerous radiowave propagation models, sub-models, and computer codes not listed but known to exist. Identification of these models is in progress and a future report will take up this matter in some detail.

6.0 User Questionaire Responses

There were twelve (12) respondees who regarded their activities as user-oriented at least in part; seven (7) were exlusively users.

6.1 Official User Needs

From the returned questionaires the following were listed as documentation of official needs:

A. USACEEIA/CC-EMCO Ft. Huachuca, AZ

1. AR 10-13. Provide radio propagation technical services to the military services and to other government agencies.
2. CCR 105-6 (Annex A). High Frequency RF system performance predictions and analysis. Antenna electrical design. Advice and special studies on propagation and antenna matters.

6.1.1 Note: The U.S. Air Force and U.S. Navy official requirements were not identified through the questionaire approach. General R and D objectives promulgated by the services typically outline the needs in these areas in broad terms. The general "Military Requirements for Satellite Data" are contained in a Joint Chief of Staff unclassified report MJCS 251-76 dtd 31 Aug 1976. Currently the U.S. Navy has no officially-documented Operational Requirement (OR) relating to solar-terrestrial or ionospheric modelling/monitoring. The view is held by staff under the Chief of Naval Operations (CNO) that Navy requirements are adequately covered by national resources including systems operated by the Dept. of Commerce (NOAA/SEL/SESC), the National Aeronautics and Space Administration (NASA), and the Air Force (AWS/AFGWC/SESS).

(It is noteworthy that Navy requirements in these areas were quite close to formalization in the late seventies when a Draft OR entitled "Environment Prediction and Assessment System" was "tabled" by CNO with the comment that such a system was ... "nice to have" ... but not affordable in view of sister service and national assets already in place.)

The U.S. Air Force, on the other hand, has promulgated a Statement Of Need (SON) -- as equivalent to the Navy OR document -- called IONSON which reflects the need for ionospheric monitoring in specific terms. In addition, another SON for solar/environmental monitoring, termed SEMSON, is now in process.

6.2 Unofficial Requirements

The following is a listing of the unofficial needs provided by that component of the "user" community which responded to the questionaires.

A. Air Force Geophysics Laboratory/Hanscom AFB, MA/USA

1. Need access to as many models as possible because one of the missions of the organization is to review and suggest improvements to ionospheric models used by operational elements of the U.S. Air Force.

B. Applied Physics Laboratory (JHU)/Laurel MD/USA

1. Need specific models which are in useable form including: magnetic field, ionospheric conductivity and ionospheric current models. Models are used for identification of disturbances, field-line tracing, and electro-dynamic studies.
2. Need monthly-averaged electron density profiles for D, E, F1, and F2 layers for day and night conditions in compact, transportable FORTRAN subroutines for the purpose of investigating propagation between the Pentagon and SSBN's in PRE, TRANS, and POST nuclear environments.

C. Centre for Radio Science/London, Ontario/Canada
   1. Need ionospheric models which include dynamic effects and effects of particle precipitation for research purposes; also to relate satellite propagation (at VHF) to (ionospheric) effects. Currently used models are semi-empirical and more refined (or physical) models would be better.

D. Los Alamos National Laboratory/Los Alamos, N.M./USA
   1. Need prediction and/or real-time assessment of electron density profiles for active experiments (go-no go criteria).

E. Naval Intelligence Environmental Sciences (NISC)/Washington, D.C./USA.
   1. Need to compare the efforts and effectiveness of other nations versus U.S. in (ionospheric) endeavors and to remain aware of the "state-of-the-art" in ionospheric predictions and their applications.

F. Naval Research Laboratory/Washington, D.C./USA
   1. Need ionospheric globularity and short-term effects which could change or affect path delays and polarization. Models are needed to devise error budgets for system designs and analysis.
   2. Need to assess communication disturbances for SATCOM and over missile links at UHF, SHF and EHF, particularly in the case of nuclear bursts.

G. RCA/Astro Electronics Division/Princeton, New Jersey/USA
   1. Need specific (computer) code representation of ionospheric models to study the relationship between topside ionosonde data and predictions based on ionospheric models.

H. Southwest Research Institute (SWRI)/San Antonio TX/USA
   1. Need global models of electron density and collision frequency versus height and need models of "real-time" electron density to support ray tracing, determination of radio propagation characteristics, predictions of system performance, and real-time system management/operation.

I. USACEEIA/CC-EMEO/Ft. Huachuca, AZ/USA
   1. Upgrade S/N requirements for HF systems.
   2. Obtain programs and hardware necessary to create and correct the input data for the ionospheric programs.
   3. Upgrade the existing noise level predictions for IONCAP.
   4. Validation of predicted reliabilities made by IONCAP.

J. U.S. Air Force Avionics Laboratory/Wright-Patterson AFB, Ohio/USA
   1. Need accurate ionospheric model to allow daily predictions of communication reliability over CONUS to polar routes of airborne satellite communication systems. This model should include the influence of magnetic index, solar flux, time of day and season on scintillation.

2. Real-time model of the (ionospheric scintillation) is needed to deduce the probability for getting a message through an airborne satellite communication system and to decide if special coding/interleaving/message repeating should be employed.

7.0 General Commentary on User Needs

There has been an almost continuous dialogue at scientific colloquia, various topical conferences, and at focussed NATO-AGARD meetings concerning the matter of user or customer needs. This stems, at least in part, from the urge for "scientific self preservation". We are well aware of the "publish or perish" admonition in academia and in other scientific institutions. In view of diminishing basic research resources relative to the size of the current ionospheric constituency, the analogue to this admonition is "technology-transfer or perish". In any case there has been a concern in the scientific community in recent years vis-a-vis relevancy of basic research and this concern was heightened by the inactment of the Mansfield Amendment by the U.S. Congress in the past decade. This precipitated numerous studies in the U.S. DoD and elsewhere to focus-in on the use of ionospheric research for example. One specific study of note was conducted for the Research and Advanced Technology Office of ODDR&E/OSD by E. Bauer and A. Krinitz of IDA [Bauer and Krinitz, 1977]. Another activity of interest was a workshop [Donnelly, 1979] held in Boulder in 1979 to address Solar-Terrestrial Predictions (See Section 7.2.1).

In addition there have been three (3) Ionospheric Effects Symposia held in 1975, 1978, and 1981 dealing with ionospheric models and scientist-user dialogue problems among other things [Goodman 1975, 1978, 1981] (See Section 7.2.2).

7.1 IDA Study of 1977

This study examined the relevance and utility of ionospheric research and anticipated future DoD needs. In view of the fact that anticipated future needs, as projected from a 1977 vantage point, may not be the 1982 current needs, it is interesting to examine some of the unclassified conclusions of that study (edited by the author of this report: JMG):

Bauer E., and A. Krinitz, 1977, "Ionospheric Research in DoD"(U), Secret Report, IDA Log No. HQ77-19163.

Donnelly R.F.(Editor, 1979, Solar Terrestrial Predictions, four volumes: Prediction Group Reports, Working Group Reports, Solar Activity Predictions, and Predictions of Terrestrial Effects of Solar Activity, U.S. GPO, Washington, D. C. 20402.

Goodman J.M. (editor), 1975, Effect of the Ionosphere on Space Systems and Communications, U.S. GPO, Washington, D.C. 20402

Goodman J.M. (editor), 1978, Effect of the Ionosphere on Space and Terrestrial Systems, U.S. GPO, Washington, D.C. 20402

Goodman J.M. (editor-in-chief), 1981, Effect of the Ionosphere on Radiowave Systems, U.S. GPO, Washington, D.C. 20402

1. No systems were identified whose performance could be improved dramatically by an improved understanding of ionospheric physics.
2. The DoD has special user and other needs which make it prudent to support technology base efforts in ionospheric physics.
3. Expertise in ionospheric physics is needed for the interpretation of potential adversary activities.
4. Certain R&D efforts deemed to be valuable to users:
   - Scintillation effects on SATCOM
   - Propagation effects on GPS
   - Propagation studies to support OTH-B
   - VLF/LF studies of MEECN
   - Propagation studies to support OMEGA
   - Special users
5. The trend (in 1977) is to go to systems which are user dependent on the ionosphere.
6. Directed research for ionospheric model development and predictions would best satisfy DoD-unique needs.

7.1.1 Commentary on the IDA Study (JMG)

The first conclusion is likely as true today as it was in 1977, the second conclusion is simply a recommendation, and the third conclusion is obviously still true. On the basis of a value assessment, the systems listed in conclusion #4 were identified. We note with interest that HF communications is not listed, the presumption in 1977 being that SATCOM would be the future primary mode of communications with HF as backup. This (1977) view is amplified in conclusion #5. Finally the study concludes that directed research is the best way to pursue the areas of model development and predictions.

It is now worth noting that HF as a communications medium is no longer viewed to be increasingly subordinate to SATCOM. It is recognized to have a place in the future DoD C^3I "architecture", and as a result of this reassessment, the fifth (#5) conclusion reached in the IDA 1977 study is only partially correct today. Furthermore the "systems-list" in conclusion #4 should be augmented to include HF communications. The Defense Nuclear Agency and the Office of the Secretary of Defense recently sponsored an adaptive HF conference to examine existing HF technology and numerous DoD-sponsored HF working groups have been established to promulgate HF improvement programs. Some improvements utilize ionospheric sounders, some involve updated models, but most are based upon the development of robust systems which perform frequency management in a manner which is organic to the system. Nevertheless since most approaches to HF improvement involve MUF-seeking architectures, the ionosphere is clearly involved. The IDA study indicates that predictions (i.e. models) of the HF channel (i.e. the ionosphere) must compete with real-time sounding of the ionosphere, but implies that HF improvements could be achieved by updating skeletonized models with sounder or satellite data. Recent NRL studies have shown that mean morphological models are useful in connection with sounder data input. Various models are being investigated in this regard including MINIMUF (resident in the NOSC/PROPHET system), IONCAP, the Rodney Bent model, and a model developed by Ching and Chiu (see bibliography at the end of this report).

A considerable amount of SATCOM-related propagation work, has been conducted since 1977 and as a result the physical understanding of the equatorial scintillation environment is rather sound. However details of the morphology and application of existing knowledge to solve the problem of quasi-real-time forecasting is not well advanced at this time. Much of the current and future attention in the scintillation area is directed toward higher latitudes where considerable work needs to be done.

7.2 Meetings and Symposia Dealing with User Needs

7.2.1 Solar-Terrestrial-Predictions Workshop - Boulder 1979

Of particular interest in the proceedings of this workshop are sections on Communications Predictions (Section III of volume 2 prepared by A.P. Mitra, B.M. Reddy and J. Klobuchar) and Ionospheric Predictions (Section VI of volume 2 prepared by R.R. Vondrak et al). The reader is referred to these sections for an elucidation of the state-of-the-art and model needs for both ionospheric-reflected and trans-ionospheric propagation.

7.2.2 Ionospheric Effects Symposia, 1975, 1978, 1981; Washington, D.C.

These conferences dealt principally with DoD problem areas of current interest. Ionospheric models and ionospheric effects on specified systems were covered.

7.2.3 NATO-AGARD Meetings

One of the most fruitful activities for reviewing (and presenting) past, current, and planned-future ionospheric research (and model development) to support specific user needs is the series of meetings held by the Electromagnetic Wave Propagation Panel (EPP) of the Advisory Group on Aerospace Research and Development (AGARD) under the aegis of NATO. Unlike many conferences, the proceedings including full papers as well as discussion periods are documented and copies are available through the DDC.

8.0 Organizational Activities of Importance to Ionospheric Prediction and Modeling

8.1 CCIR Activities

Study Group 6 of the CCIR deals with international standards and issues relating to ionospheric radiowave propagation. It plays a role in coordinating the various (U.S. and foreign) models and techniques for evaluating or predicting radiowave propagation characteristics. United States user needs (and requirements) surface at the U.S. study group (USSG-6) and various U.S. interim working party (IWP) and working group activities. These are folded into the international arena and the tangible outcome is a document ("green" book) published every four years based upon a Plenary Assembly of CCIR. The most recent "green" book of interest to ionospheric researchers is Volume VI of Recommendations and Reports of the CCIR, XIV Plenary Assembly KYOTO, 1978 on Propagation in Ionized Media published by the International Telecommunications Union (ITU). A new version will be published in 1982.

8.2 Activities of URSI (l'Union Radio-Scientifique Internationale)

URSI was established at the end of WW1 as a subset (union) of the International Council of Scientific Unions (ICSU) and its major purpose was the scientific study of radio telegraphy. The objectives of URSI include the

(i) promotion of international cooperation of all aspects of radio from a scientific point of view,
(ii) encourage in organizational aspects of radio research requiring international scale effort,
(iii) promotion of common standards and standards of measurement,
(iv) encouragement of publication and result dissemination,
(v) to collaborate with other scientific unions on matters of benefit to mankind,

and (vi) to stimulate and coordinate studies of the scientific aspects of telecommunications using electromagnetic waves (both guided and unguided).

Currently there are nine (9) commissions of URSI and the commission of primary interest in connection with this report is commission G: Ionospheric Radio and Propagation including ionospheric communications and remote sensing of ionospheric media. Other commissions of interest are Commission C: Signals and systems; and Commission H: Waves in plasma. For the United States the objectives of URSI are organized through the U.S. National Committee (USNC) of the Natural Research Council (NRC), Assembly of Mathematical and Physical Sciences (AMPS).

URSI to this day remains dedicated to the science underlying radio communications although efforts have been suggested to merge its activities with the International Association for Geomagnetism and Aeronomy (IAGA) of the International Union of Geodesy and Geophysics (IUGG).

8.3 Activities of COSPAR

COSPAR was established in 1958 by the International Council of Scientific Unions (ICSU) to continue the cooperative programs of rocket and satellite research successfully undertaken during the IGY (1957-58). In 1975, balloon research was added to the charter. Three recent publications based upon symposia organized by the COSPAR Beacon Satellite group are noteworthy for the purposes of this report [Mendillo, 1976; Checcacci, 1978; and Wernik, 1981]. The first official COSPAR-sponsored conference was held in Graz, Austria in 1972; in 1974, the second conference was held in the USSR. The last two bi-annual conferences were co-sponsored by URSI.

There are, as one might expect, many joint URSI and COSPAR activities or areas of coordination. One example is the development of the International Reference Ionosphere (IRI) which is directed by Prof Rawer of FRG for both organizations.

Mendillo M. (editor), 1976, The Geophysical Use of Satellite Beacon Observations, Boston University, Boston, MA.

Checcacci P.F. (editor), 1978, Beacon Satellite Measurements of Plasmaspheric and Ionospheric Properties, IROE-CNR, Florence Italy.

Wernik A.W. (editor), 1981, Scientific and Engineering Uses of Satellite Radio Beacons, Polish Scientific Publishers, Warsaw, Poland (Conference held in 1980).

8.4 Relationships Between URSI, AGU, IEEE, and CCIR

Other organizations have had a substantial effect upon the science and technology of ionospheric modelling and propagation predictions. The American Geophysical Union (AGU) regularly holds symposia during which the basic aeronomical features of the ionosphere - both benign and disturbed - are covered. It is unfortunate that only abstracts of papers presented at these meetings are available. (Of course, the same is true for symposia sponsored by URSI; the exception arising for cases where URSI acts as a co-sponsor of some meetings, viz; COSPAR meetings. It is remarked, however, that URSI's official publication Radio Science is a more than adequate substitute for conference proceedings.) There is clearly a synergistic relationship between AGU and URSI, with the former body principally involved in the science of geophysics and URSI principally involved in the science of radio. Clearly many techniques for understanding the physics of the ionosphere, for example, involve radiowaves as diagnostic probes; and at the same time an understanding of ionospheric physics is required to explain radiowave propagation effects. In addition, the IEEE has close ties to URSI and jointly-sponsored or collocated conferences are often held to satisfy the similar interests of members of both organizations. There is no conflict between these two organizations because URSI's function is to achieve a scientific understanding of problems relating to telecommunications, and the Communications Society (for example) of IEEE is concerned with engineering and commercial aspects. In 1975, the historically close relationship between the CCIR (of ITU) and URSI were strengthened with the formation of a liaison committee URSI-CCIR to avoid duplication of work. Activities of URSI and CCIR are unavoidably intertwined, although the study/working groups of CCIR are more structured with hard deliverables requirements and the commissions of URSI function more informally, being designed primarily as an organization to promote/encourage/stimulate radio science.

8.5 Activities of SCOSTEP

The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) was organized to foster and promote solar-terrestrial physics studies. Organizationally it is comprised of scientific discipline representatives, data center representatives, international organization representatives, and committee chairman for steering functions such as MAP, MONSEE, SMY, and STP-MET. SCOSTEP sponsors (together with URSI, IAGA, and other organizations) international symposia on solar terrestrial physics.

9.0 U.S. Government Propagation Prediction Services and Related R&D

9.1 Non-DoD Government Efforts

9.1.1 Services of the NOAA Space Environment Laboratory (SEL) and it's Space Environmental Services Center (SESC)

For those who are familiar with the WW2 and Post-War services in ionospheric prediction and related services by the Dept. of Commerce, I apologize for the following historical reminder:

Since 1942, Space Environment Services have been provided under the aegis of the Department of Commerce. In 1942 the organization was located under the National Bureau of Standards unbrella and this relationship lasted until

1965. The original name of the organization was the Interservice Radio Propagation Laboratory (IRPL) but in 1946 it was renamed the Central Radio Propagation Laboratory (CRPL). In 1954 the laboratory was moved to Boulder, Colorado, the current location, and in 1965 the activity was run by the Space Disturbances Laboratory of the Environmental Science Services Administration (ESSA). Subsequently in 1970 and at present, the activity was associated with the Space Environment Laboratory (SEL) of the National Oceanic and Atmospheric Administration (NOAA). It is noteworthy that the activity was designated in 1968 by the Federal Council of Science and Technology as the center for providing or arranging for the provision of all space weather services for the nation [Williams and Leinbach, 1982].

The Space Environment Laboratory [Williams and Leinbach, 1982] provides "space environment monitoring, forecasting, alert and warning services on a continuing 24-hour per day basis, conducts research in solar terrestrial physics in support of long-range service needs, and is responsible for developing technique to improve the services provided".

Certain services of the Space Environmental Services Center (SESC) are joint with the Air Weather Service (AWS) of the U.S. Air Force. The joint AWS/SEL service operations include: SESC operations, real-time data services, high latitude monitoring, GEOS/TIROS space environment monitoring, and operation of the solar-optical and radio observatory network.

The products offered include: real-time forecasts, warnings and alerts of solar flares and geomagnetic activity; short and medium-term forecasts of the same; geophysical alert broadcasts on WWV; solar and geophysical conditions on recorded telephone; special support; duty forecaster support via telephone; archival support; and various solar-geophysical publications.

The Space Environment Lab operates a large real-time data base to provide warnings and forecasts. This data base includes data from satellites which monitor solar emissions, energetic particles and geomagnetic fields. There are also ground-based observations of solar-optical and radio data and the Lab runs 26 ground-based magnetometers for assessing geomagnetic disturbances. The laboratory also runs an interactive computer system (updated in real-time) for direct access by qualified users (SELDADS).

9.1.2 Institute for Telecommunication Sciences (ITS)

As the title of the organization suggests, the ITS has been involved heavily in a variety of R&D efforts relating to the science of telecommunications. They should also be regarded as being in a leadership position in the area of ionospheric heating modification and a number of other ionospheric studies having telecommunication implications. For the purpose of this report, most noteworthy is the development of specific radiowave propagation models including ITS-78 and IONCAP. Scientists at ITS work closely with the commercial and academic world as well as DoD on a wide range of telecommunication issues having domestic as well as international repercussions. In this connection ITS, through its personnel, is heavily involved in CCIR activities. Currently, the chairman of CCIR study group 6 (ionospheric propagation) is Dr. C. Rush of ITS.

Williams D.J. and H. Leinbach, 1982, Letter and attached Laboratory fact sheet (R43:DJW/HL dtd Feb 16, 1982), U.S. Dept. of Commerce NOAA/ERL.

9.2 DoD Efforts

9.2.1 U.S. DoD ECAC Initiatives in Model Specification and Validation

One of the objectives of the effort embodied in this preliminary report is to evaluate as well as enumerate various ionospheric and radiowave propagation models. While the effort was underway, another effort was initiated by the U.S. DoD Electromagnetic Compatibility Analysis Center (ECAC) [See Velie and Rigler, 1981] for NADC. The ECAC study is based upon the need (requirement) for analysis and prediction both in the near and long term. Of the numerous models evaluated, there were several which are included in the body of this report. They are naturally propagation-oriented, but ionospheric properties are contained within these models which are basically empirical in nature. The following listing are models (codes) of interest in the present context.

TABLE VI

MODEL NAME	CODE NAME	DEVELOPER
High Frequency Communications Assessment Model	HFCAM	ECAC
HF Electromagnetic Compatibility	HF EMC^2	NOSC
HF Maximum Usable Frequency Evaluation	HF MUFES-4	ITS
Ionospheric Comm Analysis and Prediction Program	IONCAP	ITS
Minicomputer Model for Predicting the MUF in HF Comm	MINIMUF	NOSC
Propagation in the Earth-Ionosphere Waveguide I	MODE CONVERSION	NOSC
Propagation in the Earth-Ionospherie Waveguide II	MODESRCH	NOSC
Effect of Nuclear Burst on HF Communications	NUCOM	SRI
Program for the Analysis of Comm Satellite Systems	PACSS	ESD
Propagation Forecasting and Assessment System	PROPHET	NOSC
Quiet-Time Lowest Usable Frequency	QLOF	NOSC
HF MUFES-4 Ionospheric Propagation Model	RADARC	NRL
Satellite Propagation Model	SATPROP	ECAC
Sudden Ionospheric Disturbance Grid	SIDGRID	NOSC
HF Skywave Propagation Model	SKYWAVE	ITS
VLF and LF Propagation Model	VLF/LF	ECAC
X-Ray Flare and Shortwave Fade Duration Model	XRAY FLARE	NOSC

The ECAC study identified "principal models" based upon their requirements. They included IONCAP and MINIMUF from the above list.

9.2.2 U.S. Army Efforts

9.2.2.1 Propagation Engineering Services of the Electromagnetics Engineering Office (Propagation Engineering Division) of the U.S. Army Communications - Electronics Engineering Installation Agency (USA/CEEIA)

The propagation engineering services of USA/CEEIA, located at Ft Huachuca, Arizona, are detailed by Merkel [1981]. The goal of the command's program is ... "*to provide in a timely manner necessary and accurate design advice,*

Velie E.R., and S. Rigler, 1981, "NAVAIR Analysis and Prediction Model Evaluation and Capability Improvement Program", prepared for NAVAIR Development Center (NADC) Warminster, PA, 2 volumes.

Merkel M., 1981, "Propagation Prediction Services" Technical Memorandum EMEO-PED-TM-81-1 dtd April 1981.

frequency selection data and performance predictions to both frequency managers and operations personnel of radio units...." The four (4) broad categories include:

a) electromagnetic system performance analyses
b) electrical design and performance determination of antennas
c) electromagnetic wave propagation advice
and d) propagation forecasts and reliability predictions.

The propagation services extend from VLF to SHF. The types of propagation analyses at VLF involve estimation of field strength versus range. Antenna and system analyses are also a product of the activity. In the latter case is included radiation system efficiency, power gain, path loss determinations, receive site noise level estimation, receive antenna system directivity, and S/N estimates for communication quality determination. Some qualitative nuclear effects are analyzed.

At low frequencies (30-300 KHz), which are not used extensively by the U.S. Army, both skywave and surface wave analyses are performed. Antenna and system analyses are performed at LF also.

The USACEEIA activity combines MF and HF into one grouping due to the commonality of propagation modes. The activity produces no regular MF propagation charts or forecasts but over 210,000 HF charts are prepared annually for customers within DoD and other government agencies. The USACEEIA ground wave prediction program may take the conductivity of different soil types into account as well as heavy forestation and ground cover. The skywave prediction techniques employed by USACEEIA are based upon a joint effort with ITS-Boulder. In essence, it is a variation of the IONCAP program developed by ITS. The deliverables of the skywave prediction program include ray elevation angles, usable frequencies (LUF, MUF), and path loss. Path conditions predicted include: probability of the seven most predominant modes, take-off angles, virtual height of the ionospheric reflecting surface, signal time delay, free space path loss, absorption loss, ground reflection loss, signal levels/statistics, and noise levels. A variety of antenna types are analyzed at USACEEIA and periodic frequency reliability tables are produced.

In the VHF/UHF/SHF bands a variety of analyses are performed and numerous computerized models are employed.

9.2.2.2 Radiowave Propagation Studies in the Army

Scientists at the U.S. Army Communications Systems Center of the Communications R&D Command (CORADCOM) have contributed significantly to our current understanding of the total electron content of the ionosphere/plasmasphere and its morphology. The work of Dr. H. Soicher and his colleagues is worthy of note.

9.2.3 U.S. Navy Efforts

The U.S. Navy relies heavily on its sister services, the U.S. Air Force and the U.S. Army, for support in the area of propagation prediction. It also obtains considerable input from the NOAA/SEL organization in Boulder. For support of HF propagation in the vicinity of and under the control of the specified Communication Area Master Stations (CAMS), the U.S. Navy sanctions the publication of HF propagation forecasts (based upon future-predicted sunspot numbers) in the form of a document called NTP-6 Supp 1. The operational service support is obtained through data supplied by the AWS/SESS of Offutt AFB, Omaha, Nebraska. Scientific data is obtained from NOAA/SEL/SESC to support civilian Navy Laboratory research programs. As an example, NRL daily obtains solar-terrestrial data from the SEL data base SELDADS (SEL Data Acquisition and Display System) for use in support of the scientific programs involving radiowave propagation and ionospheric research.

The Fleet Numerical Weather Center (FNWC) is responsible for computational support in areas of sea state and tropospheric weather predictions. There is no plan for FNWC to offer propagation prediction services to Navy users since the view is held that these services are adequately handled elsewhere. Nevertheless Navy Laboratories have through the years contributed to the U.S. Fleet requirements for ionospheric-propagation information. Much of the practical work has been carried out at the Naval Ocean Systems Center (NOSC) and leading edge R&D has been conducted at NRL.

9.2.3.1 A Synopsis of Model Developments and Prediction Studies at NOSC

Rose [1981] has described the Navy-developed PROPHET system since its inseption. The current version of PROPHET, which is based upon mini-computer technology, features over 15 HF prediction and assessment models. The NOSC efforts also include scintillation and long-wave modelling. Earlier versions of PROPHET included SOLRAD-PROPHET, the purpose of which was to exploit the real-time data retrieved from the two Navy SOLRAD HI satellite systems. Subsequently CLASSIC PROPHET was developed for the purpose of multi-station HF prediction and serving principally the needs of the HF-DF community. To serve the needs of the SIGSEC and COMSEC communities, the Tactical Prediction Module (TPM) was developed. A current development is embodied in ADVANCED PROPHET, the purpose of which is to maintain a test-bed for basic and exploratory research in forecasting technology. The success of the PROPHET concept is exhibited in spinoffs which satisfy certain short-term needs of the operational community. They include: FAA-PROPHET, FOTACS, and [illegible]PS-MOD. The PROPHET technology is also contained in a U.S. Army system or APES, the Army PROPHET Evaluation System.

Rose, 1981, "PROPHET - An Emerging HF Prediction Technology" in Effect of the Ionosphere on Radiowave Systems, J. M. Goodman (editor-in-chief) U.S. GPO Washington, D. C.

Table VII below is a listing of models contained within the ADVANCED PROPHET architecture:

TABLE VII

Model	System	Action	Status
Flare detection	All hf, vlf navigation and comm	hf comm-freq shift reroute traffic	operational
Flare detection	all hr, vlf nav/comm	hf comm-freq shift reourte traffic	operational
SID GRID	all hf	hf comm freq shift reroute traffic	operational
SPA/vlf	vlf nav Omega	phase correction factor	developed
SPA inversion	all hf, vlf	estimate x-ray flare size (independent of satell.) feed sid grid	in progress
PCA/vlf	vlf navig	phase correction factor for trans-polar circuits	developed
PCA/hf	all polar hf	hf comm-advice signal strength loss-freq shift	developed
PCA/vhf	all polar satellite	vhf comm-advice signal loss	developed
QLOF	all hf	hf comm-normal operations, freq management	operational
LOF split	covert hf systems	opt freq selection against known rcvrs	operational
MINIMUF-5	all hf	hf comm-normal ops freq management	operational
15 min update to MINIMUF using auroral E fields	all hf	correct MUF est. (real-time) minimize errors to ~ 1 MHz) (feeds MINIMUF)	in progress
RAYTRACE	all hf	hf comm-normal ops. antenna selection	operational
Launch angle multipath using quasi parabolic	all hf	hf comm-normal ops. antenna selection	operational
Polar and auroral ionosphere	all hf vhf sattelite	hf comm-normal ops. polar circuits	in progress
Earth's magnetic field variations (ground)	ASW & any magnetically sensitive	corrections for field changes D_{st} and AE	in progress near completion
Mixing shock front from auroral disturbances	all hf	hf comm-midlatitude (feeds MINIMUF)	in progress
Scintillation grid	vhf/uhf satellite comm	advisory-dB fade probability based on location	operational
Omega correction factors	Omega vlf	correction factors	operational
HFFIELDS	hf	Diurnal MUF/LUF predictions with simplified field strength approximations	Operational
Ionospheric storm	hf	opt freq selection due to propagation changes	in progress
Ionogram	hf	optimum frequency selection	operational

Courtesy R. Rose, NOSC; in Rose [1981], (See bibliography in Appendix A).

9.2.3.2 Naval Research Laboratory Studies

NRL has an illustrious history in connection with ionospheric research and radio studies starting with the experimental verification of the ionosphere itself. Taylor and Hulburt [1926], of the newly-formed laboratory, sketched out the properties of the radio-reflecting layer including its day-night variations, seasonal changes, latitude effects, and general electromagnetic properties including estimates of the free electron number density. They also encountered and described the new phenomenon of "ship distance". Their early efforts fostered a strong radio engineering and physics program at the Laboratory leading to Navy development of conventional and over-the-horizon radar. The space program at NRL eventually gave rise to the U.S. National Aeronautics and Space Administration; and NRL still maintains a strong core program in space, solar, ionospheric, and terrestrial physics.

NRL has developed a number of satellite systems, and noteworthy among these for the purpose of this report is the SOLRAD series of spacecraft. The last of these, SOLRAD HI (or SOLRAD 11a/11b), consisting of a pair of spacecraft was successfully launched in 1976 into a supersynchronous orbit to monitor solar plasma beyond the magnetosphere as well as solar x-ray and ultraviolet flux. The data extracted from this twin-satellite system was downlinked to NRL in real-time, converted to engineering units and shortly transmitted to NOSC for the purpose of insertion into a variety of computer codes for near-real-time prediction of propagation effects on Navy systems. The outgrowth of this program was the NOSC/SOLRAD PROPHET computer system. Although the SOLRAD satellite data stream ceased functioning prior to 1980, NOSC continued its development of the PROPHET system for ionospheric assessment and prediction service to the FLEET and other users.

NRL is now involved in the study of various models which are best suited for ionospheric prediction in the short-term. Beginning in 1980, NRL 4180 initiated the study of a concept whereby specified remote sensing techniques could be applied to empirical models of the ionosphere to better assess propagation conditions at HF. Good results have been obtained using topside sounders as well as terrestrial oblique chirp sounders as update tools. The NRL update technique has been tested in the North Atlantic, the mid-Atlantic, and the Pacific/Indian Ocean zones with the result that rms errors in MUF predictions have been substantially reduced as compared to stand-alone modelling estimates. Customers have included NAVELEX, NAVSECGRU, and CINCLANTFLT. Future efforts will support U.S. Army and DCA requirements. Certain aspects of the work are coordinated with NOSC.

Recent studies have been detailed in several recent NRL reports [Uffelman, 1981; Uffelman and Harnish, 1981, 1982; and Uffelman et al, 1982].

NRL, and specifically the Plasma Physics Division, have long been involved in basic physics modelling of the benign and disturbed ionosphere, with the

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Taylor and E.O. Hulburt, 1926, Phys. Rev. 27, 189.

Uffelman D.R., 1981, "HF Propagation Assessment Studies Over Paths in the Atlantic" NRL Memo Report 4599.

Uffelman D.R. and L.O. Harnish, 1981, "HF Systems Test for the SURTASS Operation of Feb 1981", NRL Memo Report 4600.

Uffelman D.R. and L.O. Harnish, 1982, "Initial Results from HF Propagation Studies During SOLID SHIELD", NRL Memorandum Report (to be published).

Uffelman D.R., J.M. Goodman, and A.J. Martin, 1982, "Ionospheric Remote Sensing Application: for HF Systems Vulnerability - Progress", NRL Memo Report (to be published).

latter being driven principally by support from the Defense Nuclear Agency. Of particular note is effort in ionospheric irregularity physics modelling [Ossakow et al, 1982] using computational physics techniques for simulation purposes. This work may ultimately be directed toward a predictive capability in terms of where irregular structures will occur and what their effect upon satellite C^3I systems will be.

9.2.4 U.S. Air Force Efforts

9.2.4.1 Air Weather Service

Geophysical forecasting and ionospheric modeling studies at the USAF Global Weather Central (GWC) have been detailed by Thompson and Secan [1979] and Tascione et al [1979]. To present a flavor of the types of services provided by AFGWC, a portion of the abstract and introduction of the paper by Thompson and Secan [1979] is provided below:

> "Advanced systems that either use or are affected by the environment above 50 kilometers require forecast support. The Air Weather Service provides a worldwide network of sensors and a central facility to monitor and forecast the state of the space environment, the sun, interplanetary field, magnetosphere and ionosphere.
>
> The Air Weather Service (AWS), through its operational forecast centers of the Air Force Global Weather Central (AFGWC), provides space environmental support to the entire Department of Defense. Although the types and intensity of support are varied, the overall driving requirement is to minimize system effects caused by impulsive solar/geophysical activity and ionospheric variations. The knowledge of these effects, preferably beforehand, provides the decision maker with information to utilize his resources effectively. AFGWC provides around-the-clock service in forecasting and specifying the aerospace environment by applying varied data to the problem. The Air Force has been active in space environment research and forecasting for over a decade".

A comprehensive review by the USAF Scientific Advisory Board ad hoc committee on Aeronomy [May 1977] addressed a number of the problems and attributes of the USAFGWC/SESC.

The Space Environment Support System (SESS) run by AFGWC has the responsibility to generate ionospheric specifications and forecasts based upon ionospheric models run on in-house computer systems. It is noteworthy that forecasting capability covers relevant solar, magnetospheric and ionospheric factors. Data arrive at the center from a variety of sources located both in

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Ossakow S.L., M.J. Keskinen, and S.T. Zalesak, 1982, "Ionospheric Irregularity Physics Modelling", NRL Memorandum Report 4741

Thompson R.L. and J.A. Secan, 1979 "Geophysical Forecasting at AFGWC", in Solar-Terrestrial Predictions Proceedings: Vol.1, edited by R.F. Connelly, U.S. GPO, Washington, D.C. 20402.

Tascione T.F., T.W. Flattery, V.G. Patterson, J.A. Secan, and J.W. Taylor Jr., 1979, "Ionospheric Modelling at Air Force Global Weather Central", in Solar-Terrestrial Predictions Proceedings: Vol 1, edited by R.F. Donnelly, U.S. GPO, Washington, D.C. 20402

space and on terra-firma. Some of the types of data sources include:

- O Solar Observing Optical Network (SOON)
- O Radio Solar Telescope Network (RSTN)
- O Magnetometer Network
- O GOES satellites
- O DMSP satellites
- O Vertical Incidence Ionosonde Network
- O Faraday Rotation (TEC) polarimeter network

Certain elements of the forecasting function are joint with NOAA/SEL/SESC (See section 9.1.1).

Ionospheric modelling has been conducted at AFGWC for some time with current stress being the development of the so-called 4-D ionospheric model. Currently this model is data-starved and the solution to this problem is dependent upon additional satellite sensors being launched. There is also the possibility of utilizing terrestrially-monitored propagation data (which can be extracted from the dual L-Band transmissions of the GPS constellation of satellites) to deduce worldwide estimates of the total electron content.

9.2.4.2 Air Force Geophysics Laboratory (AFGL)

AFGL is the R&D Laboratory for the U.S. Air Force and has been central in the development of ionospheric, magnetospheric, solar, and plasma research gains over the years. In the context of this report, it is noteworthy that most of the empirical effort in ionospheric scintillation and TEC modelling has been conducted at AFGL, and the various activities within AFGL have contributed heavily to the understanding of high latitude and equatorial phenomena and modelling.

9.2.4.3 Other U.S. Air Force Activities

Other Air Force organizations which have contributed in modelling efforts include RADC and AFAL. Air Force affiliated organizations such as Aerospace Corporation have also been users and developers of models.

10.0 Propagation Prediction Services Outside the U.S.

10.1 Forecasting and Prediction in France

Solar forecasting services are performed at the Forecasting Center in Meudon France [Simon, 1979] and short-term radio propagation predictions (in the decameter band) are carried out by the "Centre National d'Etudes des Telecommunications" located in Lannion [Lassudrie-Duchesne et al, 1979]. These predictions are confined to the "European" and "North European" zones. Data sets utilized in making weekly and daily predictions include URSIGRAMS (by TELEX), ionospheric sounders in Poitiers and Uppsala (by TELEX), an ionospheric sounder in Lannion (real-time) and a magnetometer at Lannion (real-time). Based upon analysis of prediction methods, CNET-Lannion is

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Simon P., 1979, "The Forecasting Center of Meudon France" in Solar-Terrestrial Predictions Proceedings, R. Donnelly (editor), USGPO, Washington, D.C. 20402, Vol 1, p 1.

Lassudrie-Duchesne P., A.M. Bourdilo, and H. Sizun, 1979, "The French Short-Term Radio Propagation Predictions in the HF Band" in Solar-Terrestrial Predictions Proceedings, R. Donnelly (editor), USGPO, Washington, D.C. 20402, Vol. 1, p 12.

considering formulation of ionospheric predictions by adaptive methods to account more fully for small side variations.

10.2 Forecasting and Predictions in the Federal Republic of Germany

Damboldt [1979] has described the HF propagation predictions prepared by Forschungsinstitut der Deutschen Bundespost at Darmstadt, FRG. The process of long-term prediction is dissimilar to the CCIR method but is nevertheless computer-based. In the case of short-term predictions the process is essentially manual and relies on the forecaster's ability to interpret a combination of available solar-geophysical data with field strength records.

The field strength prediction method of the Deutsche Bundespost departs from the CCIR model by accounting for the non-vanishing field strength for frequencies operating above the "classical MUF". For real antennas and especially for longer paths propagation "above-the-MUF" is caused by a number of factors including: spread F scatter, D-layer scatter, meteor scatter, auroral scatter, FAI scatter, side-scatter due to ground irregularities, sporadic E effects, and gradient-induced off-great-circle propagations. The process applied by the Deutsche Bundespost involves application of an empirical factor to "classical" MUF's extracted from the CCIR maps to obtain an "operational" MUF. The frequency range between the MUF and the LUF is computed from expressions for deviative and non-deviative absorption [Beckman, 1965].

Radiowave propagation predictions are prepared for Central Europe and the following technical parameters are involved in the calculations: transmitter power (100 watts), antenna (8 m vertical rod for ground wave and a halfwave dipole for skywave), bandwidth (3 KHz for telephony, 1.1 KHz for radio teletype, and 0.2 KHz for radio telegraphy), ground conductivity (0.003 mho/m and a permittivity of 4.0), location (50^{o}N, 10^{o}E path mid-point), and the noise environment.

The center validates its long-term predictions with measurements of signal strength from 26 distant transmitters. These measurements also serve as the basis for short-term predictions.

10.3 Forecasting and Prediction in Japan

Marubashi et al [1979] describe the geomagnetic activity forecasts made at the Hiraiso Branch of the Radio Research Laboratories. Using these forecasts HF propagation predictions have also been made although the details were not described. Results were mixed and it is felt that the short-term prediction of HF propagation by relying principally upon solar activity predictions alone is unreliable (JMG: editorial remark). The authors admit to this difficulty and suggest that the unreliability is due to lack of ability to forecast the magnitude of the geomagnetic storm itself which strongly controlled by the N-S component of the IMF (Interplanetary Magnetic Field).

Damboldt Th., 1979, "Propagation Predictions for the HF Range by the Research Institute of the Deutsche Bundespost" in Solar-Terrestrial Predictions Proceedings, R. Donnelly (editor), USGPO, Washington, D.C. 20402, Vol 1, p 25.

Beckman B., 1965, "Bemerkungen Zur Abhangigkeit der Empfangsfeldstarke von den Grenzen des Ubertragungsfrequenzbereiches, NTZ 19, S, 643-653.

Marubashi K., Y. Miyamoto, T. Kidokoro, and T. Ishii, 1979, "Forecasts of Geomagnetic Activities and HF Radio Propagation Conditions Made at Hiraiso/Japan" in Solar Terrestrial Predictions Proceedings, R. Donnelly (editor), USGPO Washington, D.C. 20402, Vol 1, p 182.

Radiowave prediction services are described by Maeda [1979]. The basic approach is allied with the CCIR method and short-term forecasts rely upon real-time application of ISS-B topside sounder data for use in forecasts. Maeda maintains that the following problems must still be addressed for fully successful HF predictions:

a) solar/geomagnetic activity predictions
b) modify existing mean models with ISS-B data
c) man-made noise input
d) irregular mode propagation
e) use ISS-B data to update models for short-term predictions

The radio disturbance warning issuance system of RRL in Japan has been described by Maeda and Inuki [1979]. Both solar-terrestrial disturbance services and HF propagation disturbance services are provided. [It is noteworthy that RRL administers the Western Pacific Region Center Tokyo which is one of five regional warning centers of IUWDS (the other four are located in Paris, Sydney, Darmstadt, and Moscow, with the world center in Boulder). URSIGRAMS such as GEOLERT, URANO and USIDS are provided over the Telex networks of the IUWDS which is maintained globally.]

10.4 Propagation Prediction Services in Australia

With respect to ionospheric predictions and warnings of ionospheric disturbances upon radio waves, there are four papers which describe Australian activity, all appearing in the Solar Terrestrial Predictions Proceedings [Cook and Davies, 1979; Wilkinson, 1979; Turner and Wilkinson, 1979; and McNamara, 1979]. The last three papers are principally relevant to the subject at hand. The Ionospheric Prediction Service (IPS) of the Dept. of Science and the Environment has developed two codes for forecasting foF2 either 1 day ahead (DALYPRED) or 0-3 hours ahead (HOURPRED). Both of these classes of forecasts are based upon the utilization of a so-called T-index which is similar in some respects to the ionospheric index IF2 due to Minnis and Bazzard [1960]. The T-index is used to develop IPS prediction maps to support HF communications.

Maeda R., 1979, "Radio Propagation Prediction Services in Japan" in Solar Terrestrial Predictions Proceedings, R. Donnelly (editor), USGPO Washington, D.C. 20402, Vol 1, p 212.

Maeda R. and H. Inuki, 1979, "Radio Disturbance Warning Issuance Systems" in Solar-Terrestrial Predictions Proceedings, R. Donnelly (editor) U.S. GPO, Washington, D.C. 20402, Vol 1, p 223.

Cook F.E. and P. Davies, 1979, "A Review of the Operations of the IUWDS Regional Warning Center at the Ionospheric Prediction Service" in Solar-Terrestrial Predictions Proceeding, Vol 1, edited by R.F. Donnelly, U.S. GPO Washington, D.C. 20402..

Wilkinson P.J., 1979, "Prediction Limits of foF2", in Solar-Terrestrial Predictions Proceedings, edited by R.F. Donnelly, U.S. GPO Washington, D.C. 20402.

Turner J.F. and P.J. Wilkinson, 1979, "A Weekly Ionospheric Index" in Solar-Terrestrial Predictions Proceedings, edited by R.F. Donnelly, U.S. GPO Washington, D.C. 20402.

McNamara L.F., 1979, "The Use of Ionospheric Indices to Make Real and Near Real-Time Forecasts of foF2 around Australia" in Solar-Terrestrial Predictions Proceedings edited by R.F. Donnelly, U.S. GPO Washington, D.C. 20402.

Minnis C.M., and G.H. Bazzard, 1960, "A Monthly Ionospheric Index of Solar Activity Based on F2 Ionization at Eleven Stations", J. Atmos. Terr. Phys. 4, 297.

10.5 Propagation Prediction Services in the USSR

The Institute of Applied Geophysics (IAG) in Moscow USSR, is essentially the equivalent of the SEL/SESC in Boulder, CO. USA. It serves as the forecasting center of the national ionospheric and geomagnetic service as well as the Eurasian Regional Warning Center of IUWDS. Short-term predictions of ionospheric and magnetic disturbances are made and long-term predictions of the MUF and radiowave propagation around the world are also produced. Short-term predictions have been given the must emphasis [Avdyushin et al, 1979]. The prediction service depends heavily upon experimental data collection based upon a network of 22 vertical incidence sounders, riometer data from high latitudes, and effects data such as SID, SWF, and SPA. In addition to IAG in Moscow, there are four regional sub-centers in Murmansk, Khabarovsk, Novosibirsk, and Tashkent.

10.6 Propagation Prediction Services in India

The Radio Science Division (RSD) of the National Physical Laboratory has been providing solar and ionospheric predictions since the middle 50's. One of the main objectives is to predict the radio environment and to give advisories concerning telecommunications which use the ionosphere as part of the channel. Predictions made for the Eastern region are similar to those based on a method developed by the old CRPL organization in the USA (now SEL). The data base upon which forecasts are made consists of 40 ionosonde stations between 52° and 292° East longitude and between 80° N and 78° S latitude [Reddy et al, 1979].

There is strong interest in the low-latitude Indian subcontinent, as one might expect, and this is discussed by Aggarwal et al [1979] in the context of HF communication with emphasis upon indexing long-term ionospheric variability.

11.0 Other Models Identified Through Interview, Personal Knowledge and Literature Search

There is a vast literature dealing with ionospheric physics and radiowave propagation through ionized media. These contain references to "models" of the ionosphere but in many cases they have never been translated to computer code and have never been tested. The literature search required to locate the models and the associated custodians is an arduous task at best. As of this writing the process is incomplete. The most expedient process for identifying models aside from literature search by computer is that of contacting organizations which are users of models and by discussions with colleagues who are actively developing models. This is now in process.

Avdyushin S.I., A.D. Danilov, A.B. Malyshev, G.N. Novikova, and P.M. Svidsky, 1979, "Forecasting Ionospheric and Geomagnetic Conditions at the IAG Forecasting Center" in Solar-Terrestrial Predictions Proceedings, edited by R.F. Donnelly, U.S. GPO Washington, D.C.

Aggarwal S., D.R. Lakshmi, and B.M. Reddy, 1979, "A Simplified Indexing of F Region Geophysical Noise at Low Latitudes", in Solar-Terrestrial Predictions Proceedings, edited by R.F. Donnelly, U.S. GPO Washington, D.C. 20402.

Reddy B.M., S. Aggarwal, and D.R. Lakshmi, 1979, "Long-Term Solar Activity and Ionospheric Prediction Services Rendered by the National Physical Laboratory, New Delhi" in Solar-Terrestrial Predictions Proceedings, edited by R.F. Donnelly, U.S. GPO Washington, D.C. 20402.

Appendix A is a list of references deemed to be of interest for modeling, forecasting and prediction of the ionosphere and propagation effects due to the ionosphere. The list, although extensive is still likely to be incomplete. On the other hand, some references may not be fully relevant to the issues addressed herein.

12.0 Discussion

12.1 Recent Reviews of Ionospheric Modelling and Predictions

A review of recent (1978-1980) progress in development of ionospheric modelling has been given by Westerlund [1981]. Of interest are reviews of E and F Region dynamics (Section 3), ionospheric aspects of plasma instabilities (Section 5), influence of the ionosphere on radio systems (Section 6), morphological models of the ionosphere (Section 7), ionization and chemistry (Section 8), stratospheric-mesospheric-ionosphere interactions (Section 9), and finally, ionospheric sounding techniques and networks (Section 11). Of particular relevance to this report preparation were section 5 (parts dealing with spread F and scintillation), section 6 (all, but especially the parts dealing with forecasting), section 7 (all, but especially the part dealing with profiles of electron density), and section 11 (all).

Another useful source of recent progress in ionospheric predictions is due to Davies [1981]. His review is based in large part upon the proceedings of the Solar-Terrestrial Predictions Conference held in Boulder, Colorado in 1979 [Donnelly, 1979]. Nisbet [1978] has reviewed operational physical models of the ionosphere and Kohnlein [1978] has reviewed electron density models.

12.2 Some Thoughts on Categorization and Utilization of Models

Davies [1981] in his review of ionospheric forecasting breaks modelling into two classes: empirical and physical. Included within the empirical model class are numerical maps of ionospheric characteristics. Davies indicates the virtue of combining both classes in some instances.

Nisbet [1978], in his review of operational physical models of the ionosphere, defines three basic classes: mean morphological, dynamic, and forecasting. He maintains that the forecasting class is closely related to the mean morphological class of models. Using Nisbet's recipe, certain physical models could belong to either the mean morphological class or the dynamic class; whereas certain empirical models could belong to either the mean morphological or forecasting class. It is worth noting that almost any physical or empirical model can be used as a tool in forecasting although that may not be the original intent. They can certainly be useful in system design studies which require ionospheric vulnerability analyses to be performed.

Westerlund S., 1981, "Ionospheric Radio and Propagation" Chapter 8 of Review of Radio Science 1978-1980 edited by S.A. Bowhill, URSI publication, Brussels, Belgium.
Davies K, 1981, "Review of Recent Progress in Ionospheric Predictions", Radio Sci. 16(6) 1407-1430 (also appearing in Proceedings of IES '81).
Donnelly, 1979, cited earlier.
Nisbet J., 1978, "Operational Physical Models of the Ionosphere" in NATO/AGARD Conference Proc., Ottawa, Canada.
Kohnlein W., 1978, "Electron Density Models of the Ionosphere", Rev. of Geophy and Spa. Phys. 16 (3).

Predictions based upon physical models, other than those used for system design, may not be useful in relation to quasi-adaptive empirical models. Most certainly, short term forecasting requirements depend heavily upon the empirical approach having been suitably modified to allow update through injection of remotely-sensed ionospheric parameters. However some empirical models suffer over areas where the original data sets for model construction are sparse. For near-term forecasting the most advisable approach is to utilize an empirical mean morphology augmented by a physical model to extrapolate the model (or make it more accurate) in regions which are represented by an inadequate data set (i.e., over ocean areas or some portions of the Southern Hemisphere). For removing biases in this quasi-empirical approach, it must be made adaptive and one approach might be to inject the model with "fresh" data, from sounders, for example. In addition, certain modules must be added to account for time-varying solar and magnetic activity (or substorm) influences. (It has been recommended that sunspot number and magnetic activity indices be replaced by more physically meaningful parameters. Solar flux in the ultraviolet and x-ray bands and the Akasofu E parameter should provide improvement in prediction.)

As an example of this approach, NRL, in collaboration with NOSC, is testing specified mean morphological propagation models which have the capability for real-time update and may encorporate variable external source functions (i.e., solar, geomagnetic substorm). The models being used are MINIMUF and IONCAP, the source of model update is sounder (oblique, vertical incidence and topside) data, and the external source functions are parameters Kp and 10.7 cm. solar flux (or sunspot number). The approach has shown promise but is yet to be validated in the context of being operationally useful.

It is important to understand that certain classes of ionospheric variability are currently impossible to forecast irrespective of the complexity and elegance of the model being used. These include as a minimum: TID's and spread F (plumes). These phenomena introduce important perturbations on various C^3I systems. Better physical models <u>may</u> provide better insight regarding the likelihood of occurrence of these phenomena and even a rough estimate of their properties (i.e., time duration, spatial extent, magnitude, etc.) but it is unlikely to yield an answer for a particular point in space-time. The only solution visualized at this time is real-time mapping with good spatial and temporal resolution, perhaps from space. The fusion of data from networks of sounding stations or polarimeters may be useful for producing snapshots of the ionosphere but these "pictures" would be of limited clarity because of finite number of stations in the networks - a consequence of both economics and global topography. It would be ideal if a satellite-borne remote sensing device could "map" the ionosphere and produce snapshots of ionospheric "weather" similar to those obtained to estimate "tropospheric weather" patterns. Current approaches using topside sounders such as the Japanese ISS-B [RRL, 1981] produce "time-exposures" too large to be useful in the short-term context. Satellite-borne scanning devices have offered considerable promise, but are limited in application at present. DMSP mosaics of the auroral zone luminosity have yielded significant information about auroral phenomena but the developments cannot be followed on the sunlit side of the earth. It is speculated [Rust and Bernstein, 1981]

RRL, 1981, "Atlas of Ionospheric Critical Frequency (foF2) obtained from Ionosphere Sounding Satellite-b Observation (Part 3), January to June 1978", Radio Research Laboratories, Japan.

Rust D.M. and P. Bernstein, 1981, "Application of X-ray Imaging Techniques to Auroral Monitoring" in <u>Effect of the Ionosphere on Radiowave Systems</u> edited by J.M. Goodman, F.D. Clarke, and J. Aarons, USGPO Wash., D.C.

that x-ray imaging may be used to partially resolve this problem but benign non-auroral properties cannot be examined by this technique. Huffman et al [1981] have suggested that ionospheric and auroral measurements are possible by using vacuum ultraviolet techniques. Support for this suggestion may be found in the OGO-4 and the STP S3-4 satellite experiences. NRL scientists are also interested in exploring the feasibility of producing UV images of the earth from either a highly elliptical or nearly synchronous satellite platform [Meier, 1981]. For the present, however, regional morphological models which are amenable to quasi-real time update (via oblique sounders, for example) must suffice for short-term forecasting. This is the approach followed by NRL to support certain fleet exercises and DoD programs. A similar approach has been followed by AFGWC through its AF4D ionospheric model development.

13.0 Future Plans

This effort is continuing. The next step is to provide, along with the identification of all available models, a brief description of the model (or an abstract of the referenced paper if a computer code is not available). The next step is to provide detailed information about selected models including data extracted from questionaires. This is one of the ultimate goals. The final step is to assess the merits of each class of models (and in some cases specific models) in the context of user requirements. The process of assessment is yet to be determined. A better definition of specific user requirements is being pursued as a parallel effort.

Acknowledgments

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Huffman R.E., D.E. Paulson, F.J. LeBlanc and J.C. Larrabee, 1981, "Ionospheric and Auroral Measurements from Space Using Vacuum Ultraviolet Emission" in Effect of the Ionosphere on Radiowave Systems edited by J.M. Goodman, F.D. Clarke, and J. Aarons, USGPO Wash., D.C.

Meier, R., 1981, private communication.

APPENDIX A

BIBLIOGRAPHY ON IONOSPHERIC MODELS

Aarons J., E. MacKenzie, and K. Bhavnani [1980a], "High-Latitude Analytical Formulas for Scintillation Levels," *Radio Sci.* 15 115.

Aarons J. and J. A. Klobuchar, 1978, "Ionospheric Scintillation and Total Electron Content Studies and Their Relevance to Communication and Radar Systems," in *NTC 78*, IEEE Press, New York.

Aarons J., E. Mackenzie, and K. Bhavnani 1978, "Equatorial and High Latitude Empirical Models of Scintillation Levels." *AGARD Conf. Proc.* 238 20-1-20-20.

Aarons J., 1977, "Equatorial Scintillations: A Review," *Trans. on Ant. and Prop.* AP-25 729

Aarons J., 1975, "High Latitude Morphology of Ionospheric Scintillations," in *Effect of the Ionosphere on Space Systems and Communications*. J. M. Goodman (editor), U.S. GPO Washington, D.C.

Aarons J., 1975, "Global Morphology of Ionospheric Scintillations II," AFCRL Report No. TR-75-0135, Air Force Cambridge Research Laboratories, Hanscom AFB, MA.

Aarons J., 1973, "A Descriptive Model of *F* Layer High-Latitude Irregularities as Shown by Scintillation Observations," *J. Geophys. Res.* 78 7441-7450.

Aarons J., 1973b, "A Graphical Description of Scintillation Occurrence Patterns," in *Agardograph No. 166* on Total Electron Content and Scintillation Studies of the Ionosphere, by J. Aarons (editor) North Atlantic Treaty Organization, Neuilly Sur Seine, France.

Aarons J., H. E. Whitney, and R. S. Allen, 1971, "Global Morphology of Ionospheric Scintillations," *Proc. IEEE* 59 159-172.

AGARD, 1970, "Ionospheric Forecasting," *Conf. Proc. No. 49*, V. Agy (editor).

Aggarwal S., and B. M. Reddy, 1974, "Effects of Magnetic and Solar Activity on HF Communications Via F2 Region," *Indian J. Radio and Space Phys.* 3 (4) 401-406.

Agy V., 1969, "Proceedings of Conference on Ionospheric Forecasting," *AGARD, Neuilly-Sur-Seine, France.*

Agy V. (editor), 1970, "Ionospheric Forecasting," *AGARD Conf. Proc No. 46*, NATO/AGARD.

Ahmed M., A. D. R. Phelps, and R. C. Sagalyn, 1975, "In-situ Measurements of the Structure and Sp[illegible]al Characteristics of Small Scale *F*-Region Irregularities," in *Effect of Ionosphere on Space Systems and Communications*, J. M. Goodm[illegible] [illegible]ditor), U.S. GPO Washington, D.C.

Ahmed M. and R. C. Sagalyn, 1978, "Topside Ionospheric Trough Morphology and Mid and High Latitudes," in *Effect of the Ionosphere on Space and Terrestrial Systems*, J. M. Goodman (editor) U.S. GPO Washington, D.C.

Albrecht H. J., 1959, "Further Studies on the Chordal-Hop Theory of Ionospheric Long Range Propagation," *Arch. Met. Geoph. Bioklim.* 1: 383-391.

Allen R. S., D. E. Donatelli, G. K. Hartmann, R. Leitinger, 1977, "Adaptive Mapping of Mid-Latitude Ionosphere," AFGL-TR-77-0176.

Allen R. S., J. M. Connelly and R. Vesprini, 1975, "Specification of the Thickness of the Topside of the Ionosphere," *Environmental Research Papers No. 537.*

Allen R. S., 1975, "Modelling the Topside of the *F* Region," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO Washington, D.C.

Al'pert Ya. L., 1975, "On an Outer Ionosphere Hydrostatic Model," *J. Atmos. Ter. Phys.* 37(10) 1375-1378.

Ames J. W., R. D. Egan and G. F. MacGinitie, 1970, "Short-Term Prediction of HF Communication Circuit Performance," in *Proceedings of Conference on Ionospheric Forecasting*, V. Agy. (editor) AGARD, Neuilly-Sur-Seine, France.

Anderson D. N., C. M. Rush, M. Pokempner, and F. G. Stewart, 1981, "The Applicability of Using Theoretical Models to Improve Ionospheric Maps," paper presented at *Symposium on Effect of the Ionosphere on Radio Wave Systems*, Nav. Res. Lab., Washington, D.C.

Anderson D. N., and D. W. Rusch, 1980, "Composition of the Nighttime Ionospheric F1 Region Near the Magnetic Equator," *J. Geophys. Res.* 85 569.

Anderson D. N., 1979, "Review of Theoretical Modeling in the Low Latitude Ionosphere," in *Low Latitude Aeronomical Processes*, A. P. Mitra (editor) Pergamon, New York 93.

Anderson D. N., 1976, "Modeling the Mid-Latitude *F*-Region Storm Using East-West Drift and a Meridional Wind," *Planet. Space Sci.* 24 69.

Andriyako V. A., L. F. Burlak and S. I. Kozlov, 1978, "Generalization of Empirical Models of the Altitude Distribution of Electron Concentration in a Quiet Ionosphere of Middle Latitudes," *Kosmicheskiye Issledovaniya, (Moscow)* 16(5) 705-714.

Anufrieva T. A., T. L. Gulyaeva, G. F. Kadukhin, T. N. Soboleva, and A. G. Shlionsky, 1979, "Prediction of the Parameters of the Maximum of the Vertical Electron Density Gradient," in *Solar-Terrestrial Preditive Proceedings*, R. Donnelly (editor) U.S. GPO Washington, D.C.

Anufrieva T. A. and B. S. Shapiro, 1969, "Maps of Prediction of Geometric Parameters of the F2-Layer," *Ionosfernye Issledovaniia, Sbornik Statei* No. 17 58-77.

Anufriyeva T. A., 1978, "Charts of Forecasts of the Planetary Distribution of Median Values of Geometrical Parameters of the F2-Layer and Empirical Models," *Geomagnetizm i Aeronomiia (Moscow)* 18 (3): 533-535.

Apostolov E. M., 1974, "Model of Non-Monotonically Growing *N(h)* Profiles of the Lower Ionosphere Under Non-Flare Conditions," *Pure and Applied Geophysics* (Basel) 112(4) 635-645.

"Arctic Ionosphere Modelling: Five Related Papers," *ITS Air Force Surveys in Geophysics*, No. 241 1972, p. 56

Argo P. E., and I. J. Rothmuller, 1979, "PROPHET: An Application of Propagation Forecasting Principles," *Solar-Terrestrial Predictions Proceedings* I 312 R. F. Donnelly (editor), U.S. GPO Washington, D.C.

Argo P. E., and J. R. Hill, 1976, "High Frequency Polar Cap Absorption Model: SOLRAD Application," *Naval Electronics Laboratory Center Technical Note 3249.*

Argo P. E., 1975, "Modeling Omega PCA Phase Advances," *Naval Electronics Laboratory Center Technical Report 1950*

Arnold F., and D. Krankowsky 1979, "Mid-Latitude Lower Ionosphere Structure and Composition," *J. Atmos. Terr. Phys.* 41 1127

Auterman J. L., 1962, "Fading Correlation Bandwidth and Short-Term Frequency Stability Measurements on a High-Frequency Transauroral Path," *NBS Tech. Note 165.*

Azarnin G. V. and A. B. Orlov, 1976, "Models of Daytime Lower Ionosphere for Forecasting VLF-Fields," *Geomagnetism and Aeronomy* 16(3) 454-461 Washington D.C.

Bailey D. K., 1964, "Polar-cap Absorption," *Planetary Space Sci.* 12 (5) 494-541.

Bailey R. C. and T. B. Jones, 1974, "Accuracy and Resolution of Model Ionospheres Derived from VLF Propagation Parameters," *Journal of Atmospheric and Terrestrial Physics* 36 (6) 1059-1069.

Bain W. C., 1972, "Model Ionosphere for D-region at Summer Noon During Sunspot Maximum,," *Proc IEE 119*, pp 790-796.

Bain W. C., and B. R. May, 1967, "D-region Electron-Density Distributions from Propagation Data," *Proc. IEEE* 114 1593.

Bakshi P. and W. R. Barron, 1979, "Prediction of Riometer Absorption from Solar Flare Radio Burst Characteristics," n *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO Washington, D.C.

Barabashov B. G., B. G. Kalyadin, and T. N. Remidovskaya, 1974, "Calculation on Models of Characteristics of Short-wave Multiray Propagation," *Geomagnetizm i Aeronomiya*, Moscow 14 (6) 1013-1018.

Barclay L. W., 1978, "Statistical Modelling of HF Links," AGARD Conf on *Operational Modelling of the Aerospace Propagation Environment* AGARD-CPP-238, NATO-AGARD.

Barclay L. W., 1976, "An Ionospheric Storm Model Used for Forecasting," *AGARD Conf. Proc. 173 on Radio Systems and the Ionosphere*, Athens.

Barclay L. W., 1974, "Ionospheric Prediction Techniques," *Marconi Rev.* 37 (192) 51-66.

Barclay L. W., 1973, "H. F. Predictions and Ionospheric Forecasting," *Point-to-Point Commun.* 17 (1) 25-33.

Barclay L. W., 1970, "A Manual Ionospheric Prediction Method Used for System Planning," *Proceedings of Conference on Ionospheric Forecasting* 8.

Barclay L. W., 1962, "Variations in the Relation Between Sunspot Number and I_{F2}," *J. Atmos. Terrest. Phys.* 24 547-549.

Barghausen A. F., J. W. Finney, L. L. Proctor, and L. D. Schultz, 1969, "Predicting Long-term Operational Parameters of High-frequency Sky-wave Parameters of High-Frequency Sky-Wave Telecommunication Systems," *ESSA Tech. Rep. ERL-110-ITS 78*, Environ. Sci. Serv. Admin., Boulder, Colo.

Baron M. J., 1974, "Electron Densities Within Aurorae and Other Auroral E-Region Characteristics," *Radio Science* 9 341-348.

Bartholomew R. R., 1970, "Use of Backscatter Measurements to Improve HF Communication Predictions," *Proceedings of Conference on Ionospheric Forecasting 5.*

Basu S. and J. Aarons, 1980, The Morphology of High-Latitude VHG Scintillation Near 70 W," *Radio Sci.* 15 59.

Basu S. and S. Basu, 1980, "Modeling of Equatorial Phase and Amplitude Scintillations from OGO-6 and AE Irregularity Data," in *Low Latitude Aeronomical Progress*, A. P. Mitra (editor), Pergamon, New York, pp. 189.

Basu S. and S. Basu, 1979, "Model of Phase and Amplitude Scintillations from In-situ Measurements," in *Solar-Terrestrial Predictions Proceedings* 4, R. F. Donnelly (editor), pp. D1-32.

Basu Sunanda, S. Basu, and B. K. Khan, 1976, "Model of Equatorial Scintillations from In-Situ Measurements," *Radio Sci.* 11 821.

Basu S., S. Basu, J. N. Bhar, and B. K. Guhathakurta, 1976a, "Equatorial Irregularity Morphology in the Afro-Asion Sector with Ogo-6," *Space Res.* 16 427.

Basu S., S. Basu, and B. K. Khan, 1976b, "Model of Equatorial Scintillations from In-situ Measurements," *Radio Sci.* 11 821.

Basu S., 1975, "Universal Time Seasonal Variations of Auroral Zone Magnetic Activity and VHF Scintillations," *J. Geophys. Res.* 80 4725.

Bates H. F. and R. D. Hunsucker, 1974, "Quiet and Disturbed Electron Density Profiles in the Auroral Zone Ionosphere," *Radio Science* 9 455-467.

Bates H. F. and P. R. Albee, 1966, "On the Strong Influence of the F_1 Layer on Medium to High Latitude HF Propagation," *Sci. Rept. UAG-R175*, Geophysical Inst., Univ. of Alaska.

Bates H. F., P. R. Albee, and R. D. Hunsucker, 1966, "On the Relationship of the Aurora to Non Great-Circle High Frequency Propagation," *J. Geophys. Res.* 71 1413.

Beaujardiere and Mc Neil, 1971, "A Fortran Program for Calculating F-Layer-Produced Scintillation," *Technical Note*, Stanford Research Institute.

Becker W., 1972, "The Standard Profile of the Mid Latitude F Region of the Ionosphere as Deduced from Bottomside and Topside Ionograms," *Space Research XII* 1241-1252.

Becker W., 1969, "The Seasonal Anomoly of the F Region at Mid Latitudes and Its Interpretation," *Electron Density Profiles in Ionosphere and Exosphere* 218-230.

Beckmann B., 1970, "Short Term Ionospheric Forecasting in Germany," *Rundjunktech. Mitt. (Germany)* 14 5 213-19.

Beckmann B., 1970, "Positive Phases and Disturbances of the Ionospheric Wave Propagation in Comparison with Solar-Terrestrial Events," *Proceedings of Conference on Ionospheric Forecasting*, V. Agy (editor), AGARD, Neuilly-Sur-Seine, France, pp 26.

Beckmann B., 1970, "Limitations of Forecasting Applications," *Proceedings of Conference on Ionospheric Forecasting*V. Agy (editor), AGARD, Neuilly-Sur-Seine, France, p. 1.
Beckmann B., 1967, "Notes on the Relationship Between the Receiving-end Field Strength and the Limits of the Transmission Frequency Range MUF, LUF," *NTZ-Comm. J.*, 6 37-47.
Beckwith R.I., 1974, "Application of Ionospheric Predictions to HF Propagation in Three Dimensions," *Radio Sci.* (USA) 9 (3) 379-85.
Behuncik J. A., 1978, "Preliminary Evaluation of a Newly-Developed Satelite-to-Satellite Ionospheric Refractions Correction Model" in *Effect of the Ionosphere on Space and Terrestrial System*, J. M Goodman (editor), U.S. GPO Washington, D.C.
Bello P. A., 1964, "Measurement of the Complex Time-frequency Channel Correlation Function," *NBS Journ. of Research* 68D 1161-1165.
Bello P. A., 1963, "Characterization of Randomly Time-Variant Linear Channels," *IEEE Trans. Commun. Syst.* CS-11 360-393.
Benedictov E. A., and Yu. A. Ignat'ev, 1979, "On the Diagnostic of F Region with the Disturbed High-Power Radio Wave, by the Method of Backscattering," *Proc. on Action of the High-Power Radio Emission on the Ionosphere, Apatity* 25.
Bennett S. M., 1970, "Prediction of Daily Fluctuation of the F-Region Plasma Frequency," *Proceedings of Conference on Ionospheric Forecasting*, V. Agy (Editors), AGARD, p. 6.
Bent R. B., S. Llewellyn, G. Nesterczuk, 1975, and P. Schmid, "The Development of a Highly Successful Worldwide Empirical Ionospheric Model and Its Use in Certain Aspects of Space Communications and Worldwide Total Electron Content Investigations," *NRL Symposioum Proceedings* AD-A023 510.
Bent R. B., S. K Lewellyn, and M. K. Walloch, 1972, "Description and Evaluation of the Bent Ionospheric Model," *SAMSO TR.* 1 72-239.
Bent R. B., S. K. Llewellyn, and P. L. Schmid, 1972, "Ionospheric Refraction Correction in Satellite Tracking," *Space Research XII.*
Bent R. B., S. K. Llewellyn, 1970, "Description of the 1965-1971 Ionospheric Model in the Definitive Orbit Determination System (DODS)," *DBA Systems*, Melbourne, Pa. USA.
Beprozvannaya A. S., A. V. Shirochkov and T. I. Shchuka, 1979, "On the Approach to Forecasting Polar Ionospheric Conditions," in *Solar-Terrestrial Production Proceedings*, R. Donnelly (editor), US GPO Washington D.C., p. 528.
Bertini F., M. T. DeGiorgio, and P. F. Pellegrini, 1975, "Ray-Tracing in the Ionosphere for Long Range Propagation Studies," submitted to *Alta Frequenza.*
Beynon W. J. G. and S. Rangaswamy, 1969, "Model Electron Density Profiles for the Lower Ionosphere," *Journal of Atmospheric and Terrestrial Physics* 31(7) 891-903.
Bhatnagar A. K. and M. Sain, 1979, "Atmospheric Radio Noise Measurements in LF/MF Bands," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO Washington, D.C.
Bilitza D., N. M. Sheikh, and R. Eyfrig, 1979, "A Global Model for the Height of the F2 Peak using M3000 Values from the CCIR Numerical Map," *Telecommun. J.* 46 549.
Blair J. C., R. D. Hunsucker, and L. H. Tveten, 1970, "Ionospheric Mapping by Backscatter," *Proceedings of Conference on Ionospheric Forecasting*, V. Agy (editors), AGARD, *Neuilly-Sur-Seine, France, p. 11.*
Bleiweiss M. P., V. E Hildebrand, and J. R. Hill, 1973, "A D-region Model which Accounts for Quiet and Disturbed VLF Propagation Phenomena," *Technical Report 1868*, Naval Electronics Lab. Center, San Diego, Ca., USA.
Bold G. E. J., 1972, "The Influence of Chordal Paths on Signals Propagating to the Near Antipode of an HF Radio Transmitter," *IEEE Trans. Ant. Prop.* AP-20 741-746.
Bold G. E. J., 1969, "Power Distribution Near the Antipode of a Short-wave Transmitter," *J. Atmos. Terr. Phys.* 31 1391-1411.
Booker H. G. and J. A. Ferguson, 1978, "A Theoretical Model for Equatorial Ionospheric Spread-F Echoes in the HF and VHf Bands," *J. Atmos. Terr. Phys.* 40 803.
Booker H. G., 1962, "Guidance of Radio and Hydromagnetic Waves in the Magnetosphere," *J. Geophys. Res.* 67 4135.
Brace L. H. and R. F. Theis, 1978, "An Empirical Model of the Interrelationship of Electron Temperature and Density in the Daytime Thermosphere at Solar Minimum," *Geophys. Res. Lett.* 5 275-278.
Bradley P. A., and M. Lockwood, 1980, "Ionospheric Predictions for HF Radio Sytems: The Future," *AGARD Conf. Proc.* 284 32-1.
Bradley P. A., 1979, "Propagation at Medium and High Frequencies," *AGARD Lecture Series* 99 3-1.
Bradley P. A., 1978, "Developments in Techniques for Predicting HF Sky-Wave Field Strengths," *AGARD Conf. Proc.* 238 10-1.
Bradley P. A., 1975, "Long Turn JF Propagation Predictions for Radio Circuit Planning," *The Radio and Electronic Engineer* 45 31-41.
Bradley P. A. and J. R. Dudeney, 1973, "A Simple Model of the Vertical Distribution of Electron Concentration in the Ionosphere," *J. Atmos. Terr. Phys.* 35 2131-2146.
Bradley P. A. and J. R. Dudeney, 1973a, "A New Ionospheric Model and its Applications," presented at U.S. URSI fall meeting, Boulder, Colorado.
Bradley P. A. and J. R. Dudeney, 1973b, "Vertical Distribution of Electron Concentration in the Ionosphere," *J. Atm. Terr. Phys.* 35 2131-2146.
Bramley E. N. and R. Browning, 1978, "Mid-Latitude Ionospheric Scintillation of Geostationary Satellite Signals at 137 MHz," *J. Atmos. Terr. Phys.* 40 1247.
Bremer J., H. Gernandt, and H. Lucke, 1980, "Global Ionospheric Absorption Measurement on Board Ships," *Gerlands Beitr. Geophys* 89 81.
Buchau J., W. N. Hall, B. W. Reinisch, and S. Smith, 1978, "Remote Ionospheric Monitoring," Ref. A, 401.
Buonsanto M. J., M. Mendillo, and J. A. Klobuchar, 1979, "The Ionosphere at L=4: Average Behavior and the Response to Magnetic Storms," *Ann. Geophys.* 35 15.
Burge J. D., J. W. King and A. J. Slater, 1973, "Mapping of foF2 by Means of Top-side Sounder Satellites," *Telecommunication Journal* 40 356-363.

Calvert W. and C. W. Schmid, 1964, "Spread-F Observations by the Alouette Topside Sounder Satellite," *J. Geophys. Res.* 69 1839-1852.

Carrara N., M. T. DeGiorgio, and P. F. Pellegrini, 1970, "Guided Propagation of HF Radio Waves in the Ionosphere," *Space Sci. Rev.* 11 555-592.

CCIR, 1978, "Short-Term Prediction of Operational Parameters for Ionospheric Radio Communications," Report 727, Geneva.

CCIR, 1978a, "CCIR Atlas of Ionospheric Characteristics, Documents of 14th Plenary Assembly," *Kyoto, Rep. 340-3*, Int. Telecommun. Union, Geneva.

Chacko C. C., 1978, "The High-Latitude Behavior of hmF2 and NmF2 Along the Noon-Midnight Meridian Under Quiet Conditions," *J. Geophys. Res.* 83 5733.

Chakrabarty D. K. and A. P. Mitra, 1974, "Theoretical Models of D-Region Electron Density Profiles Under Different Conditions," *Indian Journ. of Radio & Space Phys.* 3 76-86.

Chakrabarty D. K. and P. Chakrabarty, 1973, "Some Studies of D-Region Electron Density Profiles," *Indian Journ. of Radio & Space Phys.* 2 211-218.

Chaman Lal, 1966, "The Development of a Formula for the Seasonal and Secular Characteristics of F2-Layer Critical Frequency (ΣfoF2)," *Telecommunication Journal* 33 257-262.

Chang H. T., 1971, "The Waveguide Mode Theory of Whispering Gallery Propagation in the F Region of the Ionosphere," *Radio Sci.* 6 475-482.

Chang H. 1971b, "Whispering-Gallery Propagation in the E-Region of the Ionosphere at HF and VHF," *Radio Science* 6 465-473.

Checcacci P. F., A. M. Scheggi, 1973, "Transfer Functions of Some Ionospheric Models," *IEEE Trans. Antennas and Propag. (USA)* 21 3 400-2.

Chernishyev O. V. and T. N. Vasiljeva, 1973-1974, "Prediction of Maximum Usable Frequency (in Russian)," *Nauka* 1-2.

Chernyshev O. V., 1972, "Machine Forecasting of Parameters of the F2-Layer," *Geomagnetizm i Aeronomiya, Moscow* 12(1) 127-129.

Ching B. K. and J. M. Straus, 1977, "Ionospheric Model Effects on Thermospheric Calculations," *J. Atmos. and Terr. Phys.* 39 11-12 1389-93.

Ching B. K. and Y. T. Chiu, 1973, "A Phenomenological Model of Global Ionospheric Electron Density in the E-, F1- and F2-Regions," *J. Atmos. Terr. Phys.* 35 1615-1630.

Chiu Y. T., 1979, "An Equilibrium Model of Plasmaspheric Composition and Density," *J. Geophys. Res.* 84 909.

Chiu Y. T. and B. K. Ching, 1978, "The Response of Atmospheric and Lower Ionospheric Layer Structures to Gravity Waves," *Geophys. Res. Lett.* 5 539.

Chiu Y. T., 1975, "An Improved Phenomenological Model of Ionospheric Density," *J. Atmos. Terr. Phys.* 37 1563-1570.

Chiu Y. T., 1975, "Some Problems in Constructing Phenomenological Models of Ionospheric Electron Density," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO-008-051-00064-0.

Chvojková E., 1974a, "Radio-Path Formula: 1-Theory, Circumterrestrial Echo and Other Singularities," *Geomagnetism and Aeronomy* 14 57-66 (in Russian); 46-53 (in English).

Chvojková E., 1974b, "Radio-Path Formula: 2 Practical Applications," *Geomagnetism and Aeronomy* 14 466-494 (in Russian); 392-399 (in English).

Chvojkova E., 1969, "Formulate for Ray Path in Ionized Layers with Application to Oblique Ionogram and Duct Modes," *Radio Science* 4 23-27.

Chvojková E., 1965, "Analytical Formulae for Radio Path in Spherically Stratified Ionosphere," *Radio Science* 69D 453-457.

Clapp G. A., 1978, "Digital Data Transmission over HF Skywave Circuits: Prediction and Experiment," Ref. A, 423.

Cliver E. W., J. A. Secan, E. D. Beard, and J. A. Manley, 1978, "Prediction of Solar Proton Events at the Air Force Global Weather Central's Space Environment Forecasting Facility," Ref. A, 393.

Conkright R. O., 1977, "Data Description and Quality Assessment of Ionospheric Electron Density Profiles for ARPA Modeling Project," *NOAA TR EDS 16-NGSDC 1* 80.

Conkright R. O., 1975, "Ionospheric Models Used in Ionogram Inversion Techniques," in *Effect of the Ionosphere on Space System and Communications*, J. M. Goodman (editor), U.S. GPO, Washington D.C.

Cook F. E. and C. G. McCue, 1975, "Solar-Terrestrial Relations and Short Term Ionospheric Forecasting," *The Radio and Electronic Engineer* 45 11-30.

Cookingham R. E., 1972, "Modeling the Bottomside Ionospheric Electron Density Profile," *Rep. AFCRL-72-0340*, Cambridge Res. Lab., Hanscom AFB, Ma.

Cormier R. J., 1970, "Riometry as an Aid to Ionospheric Forecasting," *Environmental Research Papers* 343 25.

Costa E. and M. Kelley, 1976, "Calculation of Equatorial Scintillation at VHF and Gigahertz Frequencies Based on a New Model of the Disturbed Equatorial Ionosphere," *Geophys. Res. Lett.* 3 677.

Cretcher K., 1975, "Ionospheric Effects in NAVSTAR/GPS," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington D.C.

Croft T. A., 1972, "Sky-Wave Back-Scatter: A Means for Observing Our Environment at Great Distances," *Rev. Geophys. and Space Phys.* 10 73-155.

Cronyn W. M., F. Erskine, S. D. Shawhan, B. L. A. Gotwals, and E. C. Roelof, 1975, "Prediction of Ionospheric Effects Associated with Solar Wind Disturbances Using Interplanetary Scintillation Observations at 34.3 MHz," *Proc. Symposium on the Effects of the Ionosphere on Space Systems and Communications.*

Croom S., A. Robbins, and J. O. Thomas, 1960, "Variations of Electron Density in the Ionosphere with Magnetic Dip," *Nature* 185 902-903.

Dachev T. P., 1979, "Empirical Model of Night Equatorial Ionosphere on Data from RPA on OGO-6 Satellite," in *Symposium on Low-Latitude Aeronomical Processes.*

Dambolt T., 1979, "Propagation Predictions for the HF Range by the Research Institute of the Deutsch Bundepost," in *Solar-Terrestrial Predictions Proceedings*, 1, 25, R. F. Donnelly (editor), U.S. Government Printing Office, Washington, D.C., pp 25.

Damon T. D. and F. R. Hartranft, 1970, "Ionspheric Electron Density Profile Model", *Tech. Memo. 70-3*, Aerospace Environ. Support Center, Ent Air Force Base, Colo.

Dandekar B. S., 1976, "Improving the Global Ionospheric Predictions of foF2," *Air Force Surveys in Geophysics* 344 24.

Danitov A. D. and V. K. Semenov, 1978, "Relative Ion Composition Model of Mid-Latitudes," *JATP* 40 1093.

Davies K., 1981, "Review of Recent Progress in Ionospheric Predictions," *Radio Sci.* 16 (6) 1407-1430.

Davies K. and E. K. Smith, 1978, "Ionospheric Predictions," *Geophysical Predictions* 82-95, National Academy of Sciences, Washington. D.C.

Davies K., 1978a, "Ionospheric Prediction and Extrapolation," *Operational Modelling of the Aerospace Propagation Environment*, in AGARD Proc. on Conf. Preprint, CPP-238, NATO-AGARD.

Davies K., 1978b, "Forecasting and Prediction of Ionospheric Parameters", in AGARD lecture series on *Recent Advances in Radio and Optical Propagation for Modern Communications, Navigation and Detection Systems*, AGARD-LS-93, NATO-AGARD.

Davies K., 1974a, "A Model of Ionospheric F-2 Region Storms in Middle Latitudes," *Planet. Space Sci.* 22 237-253.

Davies K., 1974b, "Studies of Ionospheric Storms using a Simple Model," *J. Geophys. Res.* 79 605-613.

Davies M. J., 1973, "The Integrated Ionospheric Response to Internal Atmospheric Gravity Waves," *J. Atmos. Terr. Phys.* 35 (5) 929-959.

Davis R. M. and L. A. Berry, 1977, "A Revised Model of the Electron Density in the Lower Ionosphere," *Tech. Rep. TR111-77*, DCA, Washington, D.C.

Deshpande S. D., 1979, "D-region Prediction for Solar Flare Conditions."

Detert D. G., 1968, "Ray Tracing Simulation of HF Radio Measurements of Large Travelling Ionospheric Disturbances," *Radio Sci.* 3 (1) 33-42.

Di Toro M. J., J. Hanulec, and B. Goldberg, 1965, "Design and Performance of a New Adaptive Serial Data Modem on a Simulated Time-Variable Multipath HF Link," *IEEE 1st Annu. Communications Conv. Conf. Rec.* 769-773.

Doan J. W. and P. A. Forsyth, 1978, "Mid-Latitude Quasi-Periodic Scintillations of Satellite Beacon Signals," *J. Atmos. Terr. Phys.* 40 981.

Doherty R. H., 1979, "Unpredicted Variations in D-Region Response to Solar X-Ray Events," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO Washington D.C.

Dominici P., 1975, "Magnetic Storms and Ionospheric Forecasting Over Italy," *Radio Science* 10 (7) 699-703.

Domoslawski W., 1973, "Influence of the Ionospheric Model of the Integrated Electron Content Determination," *Acta Geophys. Pol.* 21 (4) 293-303.

Donatelli D. E., 1981, "Time Cells for Adaptive Prediction of Total Electron Content," *Radio Sci.* 16 (2) 261-9.

Donnelly R. F. (editor), 1979, *Solar-Terrestrial Predictions, Vol. I, Prediction Group Reports*, U.S. GPO Washingtion, D.C.

Donnelly R. F. (editor), 1979, *Solar-Terrestrial Predictions, Vol. II, Working Group Reports*, U.S. GPO Washington, D.C.

Donnelly R. F. (editor), 1979, *Solar-Terrestrial Predictions, Vol. III, Solar Activity Predictions*, U.S. GPO Washington, D.C.

Donnelly R. F. (editor), 1979, *Solar-Terrestrial Predictions, Vol. IV, Predictions of Terrestrial Effects of Solar Activity*, U.S. GPO Washington, D.C.

Donnelly R. F., K. Davies, and D. N. Anderson, 1979, "The Equatorial Total Electron Content and Shape Factor," *J. Geophys. Res.* 84 7359.

Du Charme E. D., L. E. Petrie, and R. Eyfrig, 1973, "A Method for Predicting the F1-Layer Critical Frequency Based on the Zurich Smoothed Sunspot Number," *Radio Science* 8 (New Series) 837-839.

Dudeney J. R., 1978, "An Improved Model of the Variation of Electron Concentration with Height in the Ionosphere," *J. Atmos. Terr. Phys.* 40 195.

Dueno B., 1963, "Interpretation of Some Sweep-Frequency Back-Scatter Echoes," *J. Geophys. Res.* 68 3603-3610.

Du Long D. D. and R. S. Allen, 1976, "Specification of Navigation and Radar Errors Caused by the Ionosphere," in *The Geophysical Use of Satellite Beacon Observations*, M. Mendillo (editor), Boston University.

Dymek M. K., 1980, "Photochemical Model of Ion Composition and Electron Density in the Ionsphere at 70-300 km," in *Aeronomical Processes*, A. P. Mitra (editor), Pergamon Press, pp. 115.

Dyson P. L. and J. A. Bennett, 1979, "General Formula for Absorption of Radio Waves in the Ionosphere," *J. Atmos. Terr. Phys.* 41 367.

Elkins T. J and C. M. Rush, 1973, "Statistical Predictive Model of the Polar Ionosphere," *Air Force Surveys in Geophysics* 267 1-100.

Elkins T. J. (editor), 1973, "Empirical Model of the Polar Ionosphere," *Air Force Surveys in Geophysics* 267 140.

Elkins T. J., 1972, "A Model of Auroral Substorm Absorption," AFCRL-72-0413, *Environmental Research Papers* 404.

Essex E. A. and J. A. Klobuchar, 1980, "Mid-Latitude Winter Nighttime Increases in the Total Electron Content of the Ionosphere," *J. Geophys. Res.* 85 6011.

Essex E. A., 1976, "Ray Tracing through Realistic Ionospheric Gravity Wave Models: A Comparison with Experimental Data from Several Different Techniques," *Journal of Atmospheric and Terrestrial Physics* 38(6) 627-635.

Essex E. A., 1975, "Ray Tracing through Realistic Ionospheric Gravity Wave Models," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Evodokimova T. S., B. E. Lyannoi, V. A. Pakhotin, and Y. N. Cherkashin, 1980, "Ground Reception of Distant Decametric Radio Signals Radiated by a Satellite," in *Proc. on Propagation of Decameter Radio Waves*, Moscow, IZMIRAN.

Fatkullin M. N., V. K. Koslov, M. P. Rudina, G. I. Gordienko and A. V. Dokutchaeva, 1978, "Model of Altitude Distribution of Collision Frequencies of Charged Particles and Other Physical Parameters of Ionospheric Plasma," in *Proc. on Ionospheric Investigations Sov. Radio* 25 16.

Fatkullin M. N., 1975, "Theoretical Models of Seasonal Variations of Electron Concentration in the Mid-Latitude Region of F2, Pt. 3," *Geomagnetizm i Aeronomiya*, Moscow 15(2) 246-250.

Fatkullin M. N., O. A. Mal'tseva, T. I. Zelenova, 1974, "Theoretical Models of Altitudinal Distribution of Electron Concentration and Different Ion Components in the Lower Part of the Mid-Latitude F-Region During Negative Disturbances, Pt. 1," *Geomagnetizm i Aeronomiya*, Moscow 14(5) 809-815.

Fedder J. A., 1974, "An Ionospheric Model for Currents, the Electric Field, and the Plasma Density in an Auroral Arc," *NRL Memo. Rept. 2691.*

Feen M. M., V. L. Pisacane and M. Sturmanis, 1975, "Prediction Techniques for the Effect of the Ionosphere on Ranging from Satellites," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Feinblum D. A. and R. J. Horan, 1973, "HILON — A Model of the High Latitude Ionospheric F2 Layer and Statistics of Regular Ionospheric Effects at Ft. Churchill, 1968," Bell Labs., Murray Hill, N.J.

Fenwick R. B., 1980, "Real-Time Frequency Management for Military HF Communications," *Telecommun.* 14 23.

Ferguson J. A. and F. P. Snyder, 1980, "Approximate VLF/LF Waveguide Mode Conversion Model," *Naval Ocean Systems Center Technical Document 400.*

Ferraro A. J., 1974, "An Experimental and Theoretical Study of the D-Region, Pt. 1, Mid-Latitude D-Region Electron Density Profiles from the Radio-Wave Interaction Experiment," *Journal of Atmospheric and Terrestrial Physics* 36(5) 741-745.

Fitzwater M. and E. Bahar, 1980, "Computer Program Description: Radio Waves in an Irregular Spheroidal Model of the Earth-Ionosphere Waveguide," *IEEE Trans. Antennas Propagat.* AP-28 591.

Flattery T. W. and G. R. Davenport, 1977, "Four Dimensional Ionosphere Model," presented at URSI meeting, Stanford University.

Flattery T. W. and A. C. Ramsey, 1975, "Derivation of the Total Electron Content for Real-Time Global Applications," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Flattery T. W., 1971, "Spectral Models for Global Analysis and Forecasting," *Air Weather Service TR-242.*

Flood W. A., 1980, "A D Region Mid- and High-Latitude Approximation to the Sen-Wyller Refractive Index Equations," *Radio Sci.* 15 797.

Folkestad K., 1968, "Exact Ray Computations in a Tilted Ionosphere with No Magnetic Field," *Radio Science* 3 81-84.

Foppiano A. J., 1975, "A New Method for Predicting the Auroral Absorption of HF Sky Waves," *CCIR Interim Working Party* Document 3.

Francis S. H., 1973, "Theory and Models of Atmospheric Acoustic-Gravity Waves and Travelling Ionospheric Disturbances," *Joint Radar Propagation Study* 52.

Fremouw E. J. and J. M. Lansinger, 1981, "Recent High Latitude Improvements in a Computer-Based Scintillation Model" in *Effect of the Ionosphere on Radiowave Systems*, edited by J. M. Goodman, F. D. Clarke and J. Aarons.

Fremouw E. J. and C. L. Rino, 1978, "A Signal-Statistical and Morphological Model of Ionospheric Scintillation," *AGARD Conf. Proc.* 238 25-1-25-24.

Fremouw E. J., C. L. Rino, A. R. Hessing and V. E. Hatfield, 1977, "A Transionospheric Communication Channel Model," *Quart Tech. Rep. 7* SRI Int., Menlo Park, Calif.

Fremouw E. J., C. L. Rino and R. C. Livingston, 1976, "A Two-Component Model for Scintillation," in *Proc. Symp. Cospar Satellite Beacon Group.*

Fremouw E. J. and C. L. Rino, 1973, "Modeling of Transionospheric Radio Propagation," *Radio Sci.* 8 213.

Fremouw E. J. and C. L. Rino, 1973, "An Empirical Model for Average F-Layer Scintillation at VHF/UHF," *Radio Sci.* 8 213-222.

Fremouw E. J. and J. F. Bates, 1971, "Worldwide Behavior of Average VHF-UHF Scintillation," *Radio Sci.* 6 863-869.

Freudberg R., 1965, "Laboratory Simulator for Frequency-Selective Fading," *Conf. Rec., IEEE Annu. Conv.*, Boulder, Colo. 609-614.

Fujitaka K., 1974, "Modeling of the Wind-Perturbed Middle Ionosphere," *Journal of Atmospheric and Terrestrial Physics* 36(11) 1883-1890.

Fukao S., T. Sato, I. Kimura and R. M. Harper, 1979b, "Seasonal Mean Structure of the Nighttime F2 Region over Arecibo," *J. Atmos. Terr. Phys.* 41 1205.

Fulton B., O. Sandoz and E. Warren, 1960, "The Lower Frequency Limits for F-Layer Radio Propagation," *J. Geophys. Res.* 65 177-183.

Gallet R. M. and W. F. Utlaut, 1961, "Evidence of the Laminar Nature of the Exosphere Obtained by Means of Guided High Frequency Wave Propagation," *Phys. Rev. Letters* 6 591.

Ganguly S., J. C. G. Walker and H. Rishbeth, 1980, "The Dynamic F2-Layer Over Arecibo," *J. Atmos. Terr. Phys.* 42 553.

Gassmann G. J., 1973, "Analog Model 1972 of the Arctic Ionosphere," *Air Force Surveys in Geophysics* 259 22.

Gassmann G. J., 1972, "Model of Arctic Sporadic E," *Air Force Surveys in Geophysics* 241 21-28.

Gassman G. J., 1973, "Analog Model 1972 of the Arctic Ionosphere," *AFCRL Air Force Surveys in Geophysics No. 259* (AFCRL-TR-73-0151).

Gassmann G. J., 1970, "Ionospheric Model for the Arctic," *Environmental Research Papers No. 332* 10.

Gautier T. N. and D. H. Zacharisen, 1965, "Use of Space and Time Correlations in Short-Term Ionospheric Predictions," *First Annual IEEE Communications Convention.*

George P. L. et al., 1974, "A New Method of Predicting Ionospheric Absorption," *Telecommunication Journal* 41 308-312.

George P. L. and P. A. Bradley, 1974, "A New Method of Predicting the Ionospheric Absorption of High Frequency Waves at Oblique Incidence," *ITU Telecommunication Journal* 3-7.

George P. L., 1971, "The Global Morphology of the Quantity $\int N\nu dh$ in the D- and E- Regions of the Ionosphere," *J. Atm. Terr. Phys.* 33 1893-1906.

Georges T. M. and W. H. Hooke, 1970, "Wave-Induced Fluctuations in Ionospheric Electron Content: A Model Indicating Some Observational Biases," *Journal of Geophysical Research* 75(31) 6295-6308.

Georges T. M and J. J. Stephenson, 1969, "HF Radar Signatures of Travelling Ionospheric Irregularities, 3D Ray-Tracing Simulation," *Radio Science* 4 679-699.

Gerard J. C. and D. W. Rusch, 1979, "The Auroral Ionosphere: A Comparison of a Time-Dependent Model with Composition Measurements," *J. Geophys. Res.* 84 4335.

Gerson N. C., 1970, "The Value of Ionospheric Predictions," *Proceedings of Conference on Ionospheric Forecasting*, V. Agy (editor), AGARD, Neuilly-Sur-Seine, France.

Gerson N. C., J. G. Hengen, R. M. Pipp and J. B. Webster, 1969, "Radio Wave Propagation to the Antipode," *Can. J. Phys.* 2143-2159.

Gerson N.C., 1968, "Ray Tracing Over a Trans-Equatorial Path. Scatter Propagation of Radio Waves," *AGARD Conference Proceedings No. 37.*

Ghosh A. B. and Y. V. Somayajulu, 1975, "Ionospheric Refraction Errors in Position Fixing Using Satellites," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Giraldez A. E., 1979, "Daytime Sporadic-E Blanketing Frequency Prediction," in *Solar-Terrestrial Predictive Proceedings*, R. Donnely (editor), U.S. GPO, Washington, D.C.

Giraldez A. E., 1978, "fbEs Prediction Method at Mid-Latitudes," *CCIR* IWP 6/8, Doc. 13 and IWP 6/3, Doc. 7.

Giraldez A. E. and I. Mesterman, 1973, "Physical Processes and Guides for Predicting Es," (in Spanish), *L.I.A.R.A. C-21.*

Gladwin C. J., 1980, "An F-Layer Model of the Ionosphere for North America," *CRC Report No. 1337.*

Goe G., G. M. Lerfald and R. B. Jurgens, 1974, "1964 Digital Data Base for Ionospheric Modeling. Part A, Bottomside Electron Density Profiles," *NOAA TM ERL SEL-35* 36.

Gola M. and A. W. Wernik, 1981, "Theoretical Scintillation Spectra of the In-Phase and Quadrature Wave Components," in *Scientific and Engineering Uses of Satellite Radio Beacons*, A. W. Wernik (editor), Polish Scientific Publishers, Warsaw, pp. 307.

Goodman J. M. (editor), 1975, *Effect of the Ionosphere on Space Systems and Communications*, U.S. GPO, Washington, D.C.

Goodman J. M. (editor), 1978, *Effect of the Ionosphere on Space and Terrestrial Systems*, U.S. GPO, Washington, D.C.

Goodman J. M. (editor-in-chief), 1981, *Effect of the Ionosphere on Radiowave Systems*, U.S. GPO, Washington, D.C.

Goutelard C., 1979, "Characterisation of the Ionospheric Channel in High Frequency Digital Transmissions," *Rev. Cethedec* (France) 16 NS79-2 69-140.

Green Jr. P.E., 1963, "Time-Varying Channels with Delay Spread. Monograph on Radio Waves and Circuits," S. Silver (editor), London.

Greifinger C. and P. Greifinger, 1979, "On the Ionospheric Parameters that Govern High-Latitude ELF Propagation in the Earth-Ionosphere Waveguide," *Radio Sci.* 14 889.

Grossi M. D. and B. M. Langworthy, 1968, "Short-Wave Ionospheric Whispering-Gallery," *IEEE Int'l Convention Digest* 88.

Grossi M. D. and B. M. Langworthy, 1966, "Geometric Optics Investigation of HF and VHF Guided Propagation in the Ionospheric Whispering Gallery," *Radio Sci.* 1 877.

Gupta A., K. M. Kotadia, W. Singer and J. Taubenheim, 1979, "A Comparison of Low and Mid-Latitude D Region Electron Densities Derived from Ground Based Radio Data," *J. Atmos. Terr. Phys.* 41 237.

Gurevich A. V. and Y. Y. Tsedilina, 1975, "Trapping of Radiation in the Ionospheric Duct During Scattering on Artificial Inhomogeneities," *Geomagnetism and Aeronomy* 15 713-715.

Hajkowicz L. A., "Morphological Aspects of Ionospheric Scintillations From a Multi-Satellite Radio Transmission System,", *J. Atmos. and Terr. Phys.* 37 (9) 1255-61.

Halcrow B. W. and J. S. Nisbet, 1977, "Model of F2 Peak Electron Densities in the Main Trough Region of the Ionosphere," *Radio Science* 12 (5) 815-820.

Hanbaba R., P. Lassudrie-Duchesne, and J. Papet-Lepine, 1979, "Propagation of Decametric Waves. Introduction to Ionospheric Forecasts," *Echo Rech.* (96) 4-17.

Handa S. and H. Maeda, 1978a, "A Numerical Study of the Lunar Tide in the Mid-Latitude F2 Region of the Ionosphere, I. Oscillations of the Electron Density," *J. Atmos. Terr. Phys.* 40 395.

Hargreaves J. K., 1980a, "The Effects of Geophysical Disturbance on the Nighttime Behavior of the Electron Content of the Mid-

Harnischmacher E. and K. Rawer, 1970, "Precursor Events for Possible Forecasting of Sporadic-E and Increased Absorption," AGARD Conference Proceedings No. 49 *Ionosopheric Forecasting*, V. Agy (editor) Paper 32.

Hatfield V. E., 1979, "HF Communications Predictions 1978 (An Economical Up-to-Date Computer Code, AMBCOM)," in *Solar-Terrestrial Predictions Proceedings*, R. F. Donnelly (editor), U.S. GPO Washington, D.C., Vol. 4, p. D2-1.

Hatfield V. E. and C. L. Rino, 1975, "Non-Rician Statistics and Their Implications for Modeling Effects of Scintillation on Communication Channels," in *Effect of the Ionosphere on Space Systems and Communicatons*, J. M. Goodman (editor), U.S. GPO Washington, D.C.

Hatton W. L., 1970, "The Impact of Adaptive Systems on Forecasting," *AGARD Proceedings of Conference on Ionospheric Forecasting*, V. Agy (editor).

Hatton W. L., 1961, "Oblique-Sounding and HF Radiocommunication," *IRE Trans. PGCS-9 275.*

Hawkins G. S. and J. A. Klobuchar, 1975, "Seasonal and Diurnal Variations in the Total Electron Content of the Ionosphere at Invariant Latitude 54 Degrees," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO Washington, D.C.

Haydon G. W. and D. L. Lucas, 1968, "Predicting Ionospheric Electron Density Profiles," *Radio Science* 3 (1) 111-119.

Haydon G. W., M. Leftin, and R. Rosich, 1976, "Predicting the Performance of HF Skywave Telecommunication Systems," *Office of Telecommunications Report 76-102.*

Headrick J. M., J. M. Thomason, D. L. Lucas, S. R. McCammon, R. A. Hanson, and J. L. Lloyd, "Virtual Path Tracing for HF Radar Including an Ionospheric Model," *NRL Memo Report 2226*, Naval Research Laboratory, Washington, D.C.

Heaps M. G. and J. M. Heimerl, 1980, "The Quiet Mid-Latitude D Region: A Comparison Between Modeling Efforts and Experimental Measurements," *J. Atmos. Terr. Phys.* 42 733.

Heckman G. R., 1979, "Predictions of the Space Environment Services Center," U.S. GPO, Washington, D.C., 322

Helms W. J., 1978, "Polar D-Region Electron Density Profiles During a Solar Proton Event," *Radio Sci.* 13 853.

Hendrickson D. H. and J. A. Klobuchar, 1980, "Variability of Ionospheric Time Delay in the Mediterranean Region," *Alta Frequenze* 49 354.

Heron M. L. and L. F. McNamara, 1979, "Transequatorial VHF Propagation Through Equatorial Plasma Bubbles," *Radio Sci.* 14 897.

Hill D. A. and J. R. Wait, 1971, "Reflection of Electromagnetic Pulses From a Perturbed Linear Ionosphere Model," *Radio Science* 6 (12) 1039-1043.

Hortenbach K. J. and F. Rogler, 1979, "On the Propagation of Short Waves Over Very Long Distances: Predictions and Observations," *Telecommun. J.* 46 320.

Hortenbach J., 1977, "Simple Correction Formula Considering Antipodal Focusing in Ionospheric Predictions," *Rundfunktech. MITT. (Germany)* 21 (4) 169-71.

Hortenbach K. J., F. Rogler, 1976, "Propagation of Short-Wave Broadcasting Transmission on Transantipodal Paths and its Prediction," *Kleinheubacher Berichte* 20 205-215.

Huang Y. N., 1979, "Solar Cycle and Seasonal Variation of the Solar and Lunar Daily Variations of Total Electron Content at Lunping," *J. Geophys. Res.* 84 6595.

Huang Y. N., 1976, "Solar Cycle Variations in the Total Electron Content at Invariant Latitude 54 Degrees," in *The Geophysical Use of Satellite Beacon Observations*, M. Mendillo (editor), Boston University.

Hughes H. G., R. J. Gallenberger, and R. A. Pappert, 1974, "Evaluation of Nighttime Exponential Ionospheric Models Using VLF Atmospherics," *Radio Sci.* 9 (12) 1109-16.

Hunsucker R. D., 1980, "E- and F-Region Predictions for Communication Purposes at High Latitudes," in *Exploration of the Polar Upper Atmosphere*, edited by C. S. Deer, J. A. Holtet, and D. Reidel, Dortrecht, Holland, p. 352.

Hunsucker (chairman, working group) et al., 1979, "High Latitude E and F Region Ionospheric Predictions," in *Solar-Terrestrial Predictions Proceedings*, R. Donnelly (editor), U.S. GPO Washington, D.C., p. 513.

Hunsucker R. D., 1979, "Morphology and Phenomenology of the High Latitude E and F Regions," in *Solar-Terrestrial Predictions Proceedings*, R. Donnelly (editor), U.S. GPO Washington D.C., p. 543.

Hunsucker R. D. and H. F. Bates, 1969, "Survey of Polar and Auroral Region Effects on HF Propagation," *Radio Science* 4 347-365.

Hunsucker R. D. and L. Owren, 1962, "Auroral Sporadic-E Ionization," *J. Res. NBS Radio Propagation* 66D (5) 581-592.

Ichinose M., R. Maeda, and S. Ito, 1980, "Short-Term Prediction of Maximum Usable Frequency for Radio Communications over the Japan Area," *J. Radio Res. Lab.* (Japan) 27 124 179-85.

IEEE, 1969, "Topside Sounding and the Ionosphere," *Proc. IEEE* 57 859-1171.

IPSD, 1968, "The Development of the Ionospheric Index," *T. Report IPS-R11*, Ionospheric Prediction Service, Sydney, Australia.

Ivanov-Kholodny G. S. and A. A. Nusinov, 1979, "Forecast of Critical Frequency and Height of Maximum Density of Mid-Latitude E-Layer," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Ivanov-Kholodny G. S. and A. V. Mikhaylov, 1977, "Selection of a System of Parameters by Modelling a Daytime F2-Region," *Geomagnetizm i Aeronomiya*, Moscow 17(1) 30-34.

Ivanov V. V., B. M. Stepanov, M. L. Fil'chenkov, 1971, "Forecasting of the Characteristics of the Normal Ionospheric E-Layer," *Geomagnetizm i Aeronomiya*, Moscow 11(6) 989-992.

Jain A. R., B. C. N. Rao and K. K. Mahajan, "Design Study of an Incoherent Scatter Radar for Equatorial Aeronomy."

Jasperse J. R., 1977, "Electron Distribution Function and Ion Concentrations in the Earth's Lower Ionosphere from Boltzmann-Fokker-Planck Theory," *Planet. Space Sci.* 25 743.

Jasperse J. R. and E. R. Smith, 1978, "The Photoelectron Flux in the Earth's Ionosphere at Energies in the Vicinity of the Photoionization Peaks," *Geophys. Res. Lett.* 5 843.

Jasperse J. R., 1975, "Electron Distribution Function in a Nonuniform, Magnetized, Weakly Photoionized Gas Application to a Model Ionosphere," *Environmental Research Papers* 514 31.

Jasperse J. R., 1976, "Boltzmann-Fokker-Planck Model for the Electron Distribution Function in the Earth's Ionosphere," *Planet. Space Sci.* 24(1) 33-40.

Jean A. G., G. R. Heckman and C. E. Hornback, 1978, "Solar Terrestrial Environment Monitoring and Forecasting at the NOAA Space Environment Laboratory," *AGARD Conf. Proc. No. 238, Operational Monitoring of the Aerospace Propagation Environment*, Neuilly-Sur-Seine, France 27-1.

Jelly D. H., 1970, "On the Morphology of Auroral Absorption During Substorms," *Can. J. Phys.* 3 48.

Joachim M., 1968, "Φ_{F2}, the Ionospheric Index Defined by Computer," *Telecommunication Journal* 35 678-679.

Joachim M., A. Gromov and P. Guillot, 1972, "Forecasting of Ionospheric Propagation Indices Φ and Φ_{F2}," *C. R. Acad. Sci. (Paris)* B 275 473-476.

Joachim M., 1969, "Ionospheric Predictions Prepared by Computer in Real Time," *International Conference on Remote Data Processing* 272

Joachim M., V. Vladimirov, P. Guillot, 1969, "Forecasting a Cycle of the Indexes and F2," *Comptes Rendus Ser.* B 269(20) 1060-1062

Joachim M., 1975a, "Graphs for Defining Ionospheric Index Φ_{F2}," *Telecommunication Journal* 42 284-290.
Joachim M., 1975b, "Long-Term Periodicity of Ionospheric Activity," *Telecommunication Journal* 42 168-170.
Joachim M. and F. Kralik, 1970, "Predicting Ionosphere Index Φ_{F2} During a Complete Cycle," *Telecommunication Journal* 37 587-591.
Joachim M., 1966a, "Study of Correlation of the Three Basic Indices of Ionospheric Propagation: R_{12}, I_{F2}, and Φ," *Nature* 210 289-290.
Johanson J. M., M. J. Buonsato and J. A. Klobuchar, 1978, "The Variability of Ionospheric Time Delays," *Effect of the Ionosphere on Space Systems and Communications*, U.S. GPO, Washington, D.C., 479.
Johnson C. Y., G. W. Sjolander, E. S. Oran, T. R. Young, P. A. Bernhardt and A. V. DaRosa, 1980, "F Region Above Kauai: Measurement, Model, Modification," *J. Geophys. Res.* 85 4205.
Johanson J. M., M. J. Buonsanto and J. A. Klobuchar, 1978, "The Variability of Ionospheric Time Delay," in *Effect of the Ionosphere on Space and Terrestrial Systems* J. M. Goodman (editor), U.S. GPO-0-277-172
Jones M. N., 1973, "On the Ionospheric Dynamo and its Two-Dimensional Representation," *Gerlands Beitrage zur Geophysik*, Leipzig 82(4) 427-432.
Jones R. M., 1968, "A Three-Dimensional Ray-Tracing Computer Program," *Radio Sci.* 3(1) 93-94.
Jones T. B., I. C. Wand, 1970, "Investigation of the Reflection Properties of Various Ionospheric Models for Radio Waves in the Frequency Range 16-3000 kHz," *Journal of Atmospheric and Terrestrial Physics* 32(10) 1705-1719.
Jones W. B., G. Hardy, 1970, "Numerical Prediction of Ionospheric Characteristics," 1968, *Technical Report ERL 76-ITS* 66.
Jones W. B. and F. G. Stewart, 1970, "A Numerical Method for Global Mapping of Plasma Frequency," *Radio Sci.* 5 773.
Jones W. B., R. P. Graham and M. Leftin, 1969, "Advances in Ionospheric Mapping by Numerical Methods," *ESSA Technical Report ERL 107*, ITS 75.
Jones W. B., R. M. Gallet, M. Leftin and F. G. Stewart, 1973, "Analysis and Representation of the Daily Departures of the f_0F2 from the Monthly Median," *OT Rep. 73-12* U.S. Dept. of Commer., Washington, D.C.
Jones W. B. and D. L. Obitts, 1970, "Global Representation of Annual and Solar Cycle Variation of foF2 Monthly Median 1954-1958," *Telecommunications Research Report OT/ITSRR3*, Boulder, Colorado, USA.
Jones W. B. and R. M. Gallet, 1960, "Ionospheric Mapping by Numerical Methods," *ITU Telecommunication Journal* 27 260-264.
Jones W. B. and R. M. Gallet, 1962, "Representation of Diurnal and Geographic Variations of Ionospheric Data by Numerical Methods," *J. Res. Natl. Bur. Stand.* Sect. D 66 419.
Jull G. W., D. J. Doyle, G. W. Irvine and J. P. Murray, 1962, "Frequency Sounding Techniques for HF Communications over Auroral Zone Paths," *Proc. IRE* 50 1676-1682.
Jull G. W., 1968, "HF Spatial and Temporal Propagation Characteristics and Sounding Assisted Communications," *Ionospheric Radio Communications*, K. Folkestad (editor), Plenum Press, New York 225-241.
Jull G. W., 1967, "Short-Term and Averaged Characteristics of Nonreciprocal HF Ionospheric Paths," *IEEE Trans. Antennas Propagat.* AP-15 268-277.

Katz A. H., M. D. Grossi, R. S. Allen and D. E. Donatelli, 1978, "Adaptive Correction of the Effect of the Ionosphere on Range Determination by Terrestrial Radars," in *Effect of the Ionosphere on Space and Terrestrial Systems*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.
Katz A. H., 1969, "F-Layer Propagation Changes During Magnetic Storms," *Proceedings of Conference on Ionospheric Forecasting*, V. Agy (editor), AGARD, Neuilly-Sur-Seine, France, p. 9.
Kawachika N. M. and O. G. Villard, Jr., 1973, "Computer Simulation of HF Frequency-Selective, Fading, and Performance of the Mode Averaging Diversity Combiner," *Radio Sci.* 8 203-212.
Keneshea T. J., R. S. Narcisi and W. Swider, Jr., 1970, "Diurnal Model of the E-Region," *J. Geophys. Res.* 75 845-854.
Kerblay T.S. and E. Kovalevskaya, 1967, "Calculation of MUF in the Presence of a Horizontally Heterogeneous Ionosphere," (in Russian), *Geomagnetism i Aeronomiya* 7 123-127.
Kerblay T.S. and E. Kovalevskaya, 1967, "Computation of the MUF in the Presence of Horizontal Ionospheric Inhomogeneity," *Geomagnetism and Aeronomy* 7 92-96.
Kerblay T. S. and E. Volochinova, 1964, "Estimation of the Tilts of the Isosurfaces of NF2 on the Basis of N h Profiles," (in Russian), *Geomagnetism i Aeronomiya* 1 61.
Kerblay T. S., 1964, "Instruction on Calculation of HF Communications Reflected from the Es-Layer," (in Russian), *Science*.
Kerblay T. S., E. M. Kovalevskaya, E. M. Zhulina and L. M. Ishkova, 1979, "Prediction of the Characteristics of a Radio Signal Reflected from Horizontally-Inhomogeneous Ionosphere and the Relevant Requirements for Prediction of Ionospheric Parameters," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.
Kerblay T. S., 1960, "Relation Between Critical Es Frequencies and Characteristics of Apparatus," (in Russian), *Ionospheric Studies* 5 50-63.
Kerblay T. S. and G. S. Nosova, 1979, "Statistical Prediction of E_s-Layer Parameters and Echo-Signal Characteristics," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.
Kersley L., J. Aarons and J. A. Klobuchar, 1980, "Nighttime Enhancements in Total Electron Content Near Arecibo and Their Association with VHF Scintillations," *J. Geophys. Res.* 85 4214.
Kersley L., 1980, "An Empirical Model of Ionospheric Slab Thickness," H. J. Albrecht (editor), *AGARD Conference Proceedings No. 284, Propagation Effects in Space/Earth Paths* 23 1-8.
Kersley L. and J. A. Klobuchar, 1978, "Comparison of Protonospheric Electron Content Measurements from the American and European Sectors," *Geophys. Res. Lett.* 5 123.
Kersley L. and J. A. Klobuchar, 1980, "Storm Associated Protonospheric Depletion and Recovery," *Planet. Space Sci.* 28 453

Keskinen M. J., R. N. Sudan and R. L. Ferch, 1979, "Temporal and Spatial Power Spectrum Studies of Numerical Simulations of Type 2 Gradient Drift Irregularities in the Equatorial Electrojet," *J. Geophys. Res.* 84 1419.

Keskinen M. J., P. K. Chaturvedi, S. L. Ossakow, and B. E. McDonald, 1981, "The Current Convective Instability and its Relation to Diffuse Auroral Scintillation-Causing F Region Irregularities," in *Effect of the Ionosphere on Radiowave Systems*, edited by J. M. Goodman, F. D. Clarke and J. Aarons, U.S. GPO, Washington, D.C.

King J. W., J. C. Samuel, G. Thuillier, 1975, "Accuracy of the CCIR F2 Layer Model at Low and Middle Latitudes," *Electron. Lett.* 11 16 366-8.

King J. W. and A. J. Slater, 1973, "Errors in Predicted Values of foF2 and hmF2 compared with the Observed Day-to-Day Variability," *ITU Telecommunication Journal* 40 766-770.

King J. W., P. A. Smith, D. Eccles, G. F. Fooks and H. Helm, 1964, "Preliminary Investigation of the Structure of the Upper Ionosphere as Observed by the Topside Sounder Satellite Alouette," *Proc. Roy. Soc.* A.281 464-487.

King J. W., 1973, "The Determination of foF2 and hmF2 from Satellite-Borne Probe Data," *Telecommunication Journal* 40 364-368.

Klein M. S., 1968, "Synthetic HF Environment," *Rome Air Develop. Cent., Final Rep., Contract F20602-67-G0162*, 1-27.

Klimov N. N. et al., 1969, "A Dynamic Model of the Ionsphere F-Region, Including Temperature Variations," *Geomagnetizm i Aeronomiya* 9(4) 655-660.

Klobuchar J. A. and R. S. Allen, 1970, "A First Order Model of Total Electron Content Group Path Delay for a Midlatitude Ionosphere," *AFCRL Tech. Rept. 70-0403.*

Klobuchar J. A., 1975, "A First-Order, World-Wide, Ionospheric Time Relay Algorithm," *AFCRL Tech. Report 75-0502.*

Klobuchar J. A. and R. S. Allen, 1970, "A First-Order Prediction Model of Total Electron Content Group Path Delay for a Midlatitude Ionosphere," *Tech Report AFCRL-70-0403.*

Klobuchar J. A., 1975, "A First-Order, World-Wide, Ionospheric Time-Delay Algorithm," *AFCRL Tech. Rep. 75-0502.*

Klobuchar J. A., H. Soicher and J. A. Pearson, 1980, "A Preliminary Evaluation of the Two-Frequency Ionospheric Correction for the NAVSTAR Global Positioning System," *AGARD Conf. Proc. No. 284* 36-1.

Klobuchar J.A. and G. S. Hawkins, 1975, "On the Determination of Mid-Latitude Ionospheric Time Delay from foF2," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Klobuchar J. A., 1981, "Present State of Ionospheric Time Delay Prediction," in *Scientific and Engineering Uses of Satellite Radio Beacons*, A. W. Wernik (editor), Polish Scientific Publishers, Warsaw, p. 357.

Klobuchar J. A., M. J. Buonsanto, M. J. Mendillo and J. M. Johanson, 1978, "The Contribution of the Plasmasphere to the Total Time Delay," *Effect of the Ionosphere on Space and Terrestrial Systems*, U.S. GPO, Washington, D.C., 486.

Klobuchar J. A. and R. S. Allen, 1973, "Total Electron Content Models," *Air Force Survey in Geophysics No. 257 AFCRL-TR-73-0098* 13-17.

Klobuchar J. A., 1979, "Trans-Ionospheric Propagation Predictions," in *Solar-Terrestrial Predictions Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C., p. 217.

Knecht R. W. and R. E. McDuffie, 1962, "On the Width of the Equatorial Es Belt," *Ionospheric Sporadic-E*, edited by E. K. Smith and S. Matsushita, Pergamon, Oxford, pp. 215-218.

Knight P., "MF Propagation: A Wave Hop Method for Ionospheric Field Strength Predictions," *BBC Engineering 100* 22-34.

Knudsen W. C., 1977, "Numerical Model of the Convecting F2 Ionosphere at High Latitudes," *Journal of Geophysical Research* 82(29) 4784-4792.

Knudsen W. C., P. M. Banks, J. D. Winningham and D. M. Klumpar, 1977, "Numerical Model of the Convecting F_2 Ionosphere at High Latitudes," *J. Geophys. Res.* 82 4784.

Kohnlein W. and W. J. Raitt, 1977, "Position of the Mid-Latitude Trough in the Topside Ionosphere As Deduced from ESRO.4 Observations," *Planet. Space Sci.* 25 600.

Konopleva E. N., 1964, "Reliability of Communications and Necessary Signal/Noise Ratio in Short-Wave Radio Channels," (in Russian), *Elektrosvyaz* 5.

Konopleva E. N. and E. A. Khmelnitsky, 1970, "Possible States of a Short-Wave Channel Depending on Propagation Conditions," *Elektrosvyaz* 12.

Kopka H. and H. G. Möller, 1968, "MUF Calculations Including the Effect of the Earth's Magnetic Field," *Radio Science* 3 53-56.

Kosikov K. M., 1959, "Oblique Return Sounding and Problems of Radio Communication and Broadcasting Over Long Distances," (in Russian), *Elektrosviaz* 7 699.

Kotadia K. M., A. Gupta and R. M. Kotak, 1979, "Determination of the Solar Cycle Variation of HF Radio Wave Absorption at Low Latitude," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Kovalevskaya E. and T. S. Kerblay, 1971, "Calculation of the Length of Hop, MUF and Angles of Arrival of Radio Waves, Taking Account of the Horizontal Irregularity of the Ionosphere," (in Russian), Nauka Publishing House, Moscow.

Kovalevskaya E. and A. A. Kornitzkaya, 1969, "Influence of the Horizontal Gradients of the Parameters of Electron Density Distribution on the MUF, Hop Distance and Angles of Arrival," *Geomagnetism i Aeronomiya* 9 232-235.

Kovalevskaya E. M. and E. M. Zhulina, 1979, "The Statistical Properties of the Disturbed High-Latitude Ionosphere in Radio Wave Propagation Computations," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Krasnov V. M., 1975, "Model of an Ionospheric Screen," *Geomagnetizm i Aeronomiya* 15(3) 551-553.

Krinberg I. A., V. A. Kuz'min, G. I. Gershengorn, 1974, "Ionospheric Model with Allowance for Plasma Motion Along Geomagnetic Lines of Force," *Geomagn. and Aeron.* 14 2 224-30.

Kuleshova V. P., E. V. Lavrova, and L. N. Lyakhova, 1979, "Forecasting of δfoF2-Variations for Ionospheric Disturbances," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Kundu M. R. J., 1960, "Solar Radio Emission on Centimeter Waves and Ionization of the E-Layer of the Ionosphere," *J. Geophys. Res.* 65 3903

Kuriki I., I. Kasuya, H. Hojo and K. Tanohata, 1974, "Analysis of Maximum Observed Frequencies on Oblique Ionograms by Ray Tracing Technique," *J. Radio Res. Labs.* 21 161-190.

Kuz'min E. L., 1971, "Determination of Critical Frequencies and Geometrical Parameters of a Parabolic Model of the Ionospheric Layer During Vertical Slant Sounding," *Geomagnetizm i Aeronomiya* 11(6) 1100-1102.

LaBahn R. W., 1974, "Development of a Scintillation Grid," *Naval Electronics Laboratory Center Technical Note* 2814.

Lang-Hesse G. and K. Rinnert, 1970, "The Reliability of Transpolar VLF Measurements as a Method to Forecast HF Propagation Disturbances," *Ionospheric Forecasting*, V. Agy (editor), AGARD Conference Proceedings No. 49 Paper No. 30.

Larsen T. R. and E. V. Thrane, 1977, "Ionospheric Effects on Loran-C in Polar Regions," AGARD conference proceedings No. 209 on *Propagation Limitations of Navigation and Positioning Systems.*

Larsen T. R., 1979, "Effect of the D-Region Ionization on Radio Wave Propagation," in *Solar-Terrestrial Predictions Proceedings* R. Donnelly (editor), U.S. GPO Washington, D.C., p. 617.

Layakhova L. N., 1973, "Quantitative Ionospheric Forecast," *Geomagnetizm i Aeronomiia* 13(1) 59-63.

Lee M. K. and J. S. Nisbet, 1975, "Propagation Predictions and Studies Using a Ray Tracing Program Combined with a Theoretical Ionospheric Model," *IEEE Trans. Ant. Prop.* AP-23 132.

Lee M. K. and J. S. Nisbeth, 1975, "Propagation Predictions and Studies Using a Ray Tracing Program Combine with a Theoretical Ionospheric Mode," *IEEE Trans. Ant. and Prop.*, p. 132.

Leftin M., 1976, "Numerical Representation of Monthly Median Critical Frequencies of the Regular *E* Region (*fo E*)," *OT Rep. 76-88* U.S. Dep. of Commer./Office of Telecommun., Washington, D.C.

Leftin M. and S. M. Ostrow, 1969, "Numerical of $f_b E_s$ for Solar Cycle Minimum," *ESSA Tech. Rep. ERL 124-ITS87*, Environ. Sci. Serv. Admin., Boulder, Colo.

Leftin M., S. M. Ostrow and C. Preston, 1978, "Numerical Maps of $fo\ E_s$ for Solar Cycle Minimum and Maximum," *ESSA Tech. Rep. ERL 73-ITS-ITS 63*, Environ. Sci. Serv. Admin., Boulder, Colo.

Leitinger R., R. S. Allen, D. E. Donatelli and G. K. Hartmann, 1978, "Adaptive Mapping of Ionospheric Features," in *Effect of the Ionosphere on Space and Terrestrial Systems*, J. M. Goodman (editor), pp. 530-537.

Lemaire J. and M. Scherer, 1974, "Exospheric Models of the Topside Ionosphere," *Space Science Reviews*, Dordrecht, Holland, 15(5) 591-640.

Le Roux Y. M., 1980, "Short-Range Ionospheric Forecasting by Mathematical Predictive Modelling," *Annales de Geophysique, Paris* 36(2) 251-262.

Lerfald G. M., C. G. Little and R. Parthasarathy, 1964, "D-Region Electron Density Profiles During Auroras," *J. Geophys. Res.* 69(13) 2857-2860.

Levine P. H., R. B. Rose and J. N. Martin, 1978, "A Simplified HF MUF Prediction Algorithm," *IEEE Conference on Antennas and Propagation*, Publication No. 169, Pt. 2 pp. 161-167.

Llewellyn S. K. and R. B. Bent, 1973, "Documentation and Description of the Bent Model—Delay Model Version," *SAMSO Rep. TR 73-252* Space and Missile Syst. Organ., Los Angeles, Calif.

Llewellyn S. K. and R. B. Bent, 1973, "Documentation and Description of the Bent Ionospheric Model," *AFCRL TR-73-0657, SAMSO TR-73-253.*

Lloyd J. L., G. W. Haydon, D. L. Lucas and, L. R. Teters, 1978, "Estimating the Performance of Telecommunication Systems Using the Ionospheric Transmission Channel," *Tech. Rept. EMEO-PED-79-8.*

Lloyd K. H. and G. Haerendel, 1973, "Numerical Modeling of the Drift and Deformation of Ionospheric Plasma Clouds and of Their Interaction with Other Layers of the Ionosphere," *J. Geophys. Res.* 78 31 7389-7415.

Lockwood G. E. K. and G. L. Nelms, 1964, "Topside Sounder Observation of the Equatorial Anomaly at 75° W Longitude," *J. Atmos. Terr. Phys.* 26 569-580.

Lockwood M., 1980, "Bottomside Mid-Latitude Ionospheric Trough," *Journal of Atmospheric and Terrestrial Physics*, Oxford 42(7) 605-615.

Lomax J. B, 1967 "High-Frequency Propagation Dispersion," Stanford Research Institute.

Lucas D. L. and G. W. Haydon, 1966, "Predicting Statistical Performance Indexes for High Frequence Telecommunication Systems," *ESSA Tech. Report* IER 1-ITSA 1 US Printing Office.

Lucas D. L., J. L. Lloyd, J. M. Headrick and J. F. Thomason, 1972, "Computer Techniques for Planning and Management of OTH Radars," *NRL Memo. Rep. 2500.*

Lyakhova L. N., L. I. Kostina, 1973, "On Quantitative Ionospheric Forecasting," *Geomagn. and Aeron.* 13 1 59-63.

Lyakhova L. N. and L. I. Kostina, 1973, "On Quantitative Ionosphere Forecasting," *Geomag. and Aeron.* 13 50-53.

Lyon G. F., 1979, "The Corrugated Reflector Model for One-Hop Oblique Propagation," *J. Atmos. Terr. Phys.* 41 5.

Lyon A. J. and L. Thomas, 1963, "The F2-Region Equatorial Anomaly in the African, American and East Asian Sectors During Sunspot Maximum," *J. Atmos. Terr. Phys.* 25 373-386.

Lyon G. F. and V. P. Bhatnagar, 1979, "Response of the Midlatitude Ionosphere to Solar Magnetic Sector Crossing," *Can. J. Phys.* 57 218.

MacLeod M.A., T.J. Keneshea, R.S. Narcisi, 1975, "Numerical Modelling of a Metallic Ion Sporadic-E Layer," Air Force Cambridge Res. Labs., Bedford, Ma., *Radio Science* 10(3) 371-388.

Madhusudhana Rao D. N., K. V. V. Ramana, 1976, "Studies on Ionospheric D and E Region Models in Conjunction with Al Absorption Measurements at Waltair," *Indian J. Radio and Space Phys.* 5 2 183-7.

Maganmohan Rao B., D. N. Madhusudhana Rao, K. V. V. Ramana, 1976, "Frequency Variation of Ionospheric Absorption in Model E and D Regions," *Indian J. Radio and Space Phys.* 5 2 158-61.

Malaga A., 1981, "A Global Model for Wideband HF Skywave Propagation," in *Effect of the Ionosphere on Radiowave Systems*, J. M. Goodman (editor-in-chief), U.S. GPO, Washington, D.C.

Malaga A. and R. E. McIntosh, 1979, "Analysis of HF Pulse Reflection from a Randomly Varying Ionosphere," *IEEE Trans. Antennas Propagat.* AP-27 508.

Mal'tseva O. A., 1969, "Methods of Computing Ionograms for a Model of The Ionosphere with a Nonmonotonic H(N) Distribution," *Geomagn. I. Aeronomiya* 9 2 348-9.

Manheimer D., "Lateral Bending Effects at the Ionospheric Height Transient," 1981, *Effect of the Ionosphere on Radiowave Systems*, edited by J. M. Goodman, F. D. Clarke and J. Aarons, U.S. GPO, Washington, D.C.

Manson A. H. and M. W. J. Merry, 1971, "Seasonal Variations of Electron Densities Below 100 km at Mid-Latitudes. Pt. 4, Preliminary Model Calculations," *Journal of Atmospheric and Terrestrial Physics* 33(3) 413-428.

Matsushita S. and Y. Kamide, 1979, "Model Calculations of Electric Fields and Currents in the High-Latitude E Region for Predictions of Ionospheric Variations," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

McDonald B.E., S.L. Ossakow, T.P. Coffey, R.N. Sudan, A.J. Scannapieco, and S.R. Goldman, 1975, "Recent Results from Theoretical and Numerical Modelling of E and F Region Irregularities," in *Effect of the Ionosphere on Space Systems and Communications*, J.M. Goodman (editor), U.S. GPO, Washington, D.C.

McDonald B.E., S.L. Ossakow, and A.J. Scannapieco, 1976, "A Nonlinear Model for Equatorial Spread F Irregularity and Scintillation Calculations," in *Symposium Proceedings of Geophysical Use of Satellite Beam Observation*, edited by St. Mandillo, Boston Univ.

McDonald B.E., T.P. Coffey, S.L. Ossakow, R.M. Sudan, A.J. Scannapieco, and S.R. Goldman, 1975, "Recent Results from Theoretical and Numerical Modeling of E and F Region Irregularities," *Ionospheric Effects Symposium*, Washington, D.C.

McDonald B.E., S.L. Ossakow, and A.J. Scannapieco, 1976, "A Nonlinear Model for Equatorial Spread F Irregularity and Scintillation Calculations," in *Symposium Proceedings of Geophysical Use of Satellite Beam Observation*, edited by St. Mendillo, Boston Univ.

McIntosh R.E. and A. Malaga, 1980, "Time Dispersion of Electromagnetic Pulses by the Ionosphere," *Radio Sci.* 15 645.

McNamara L.F., 1974, "Ionospheric Predictions on Transequatorial Circuits," *Proc. Inst. Radio and Electron. Eng.* Aust. (Australia), 35 5 117-26.

McNamara L.F., 1979b, "Model Starting Heights for N(h) Analyses of Ionograms," *J. Atmos. Terr. Phys.* 40 543.

McNamara L.F., 1974, "On Prediction Schemes for Afternoon-Type TE," *Ionospheric Prediction Service (Australia) Series R* 26.

McNamara L.F., 1979a, "Statistical Model of the D Region," *Radio Sci.* 14 1165.

McNamara L.F., 1976, "The Correlation of Individual Values of foF2 and M(3000)F2 with the Solar 10.7 cm Flux under Magnetically Quiet Conditions," *Ionospheric Prediction Service (Australia), Series R* 30.

Mechtly E. A. and D. Bilitza, 1974, "Models of D-Region Electron Concentrations," *Rept. IPW-WB1.*

Meisel D. D., B. Duke and W. D. Savedoff, 1979, "Minicomputer Simulation of Ionospheric Radiowave Propagation at Decametric Wavelengths," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Mendillo M. and J. A. Klobuchar, 1979, "A Morphology-Based Prediction Scheme for the Coupled Latitudinal and Local-Time Development of F-Region Storms," *Solar-Terrestrial Predictions Proceedings*, R. F. Donnelly (editor), U.S. GPO, Washington, D.C., 4, pp C-15.

Mendillo M. and C. C. Chacko, 1977, "The Base Level Electron Density Trough," *J. Geophys. Res.*

Mendillo M., 1973, "A Study of the Relationship Between Geomagnetic Storms and Ionospheric Disturbances at Mid-Latitudes," *Planet. Space Sci.* 21 349.

Mendillo M. and J. A. Klobuchar, 1974a, "An Atlas of the Midlatitude F-Region Response to Geomagnetic Storms," *AFCRL Tech. Report 0065.*

Mendillo M., F. X. Lynch and J. A. Klobuchar, 1979, "Geomagnetic Activity Control of Ionospheric Variability," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Mendillo M. and J. A. Klobuchar, 1975, "Investigations of the Ionospheric F-Region Using Multi-Station Total Electron Content Observations," *J. Geophys. Res.* 80 643-650.

Mendillo M., 1971, "Ionospheric Total Electron Content Behavior During Geomagnetic Storms," *Nature* 234 23.

Mendillo M. and J. A. Klobuchar, 1974b, "Seasonal Effect in Ionospheric Storms," paper presented at the COSPAR/URSI Symposium on Satellite Beacon Studies of the Ionosphere Structure and ATS-6 Data.

Mendillo M., M. J. Buonsanto and J. A. Klobuchar, 1975, "The Construction and Use of Storm-Time Corrections for Ionospheric F Region Parameters," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Mikhaylov A. V. and G. I. Ostrovskiy, 1978, "Calculation of a Nighttime Magnetoquiet F2-Region of the Middle-Latitude Ionosphere," *Geomagnetizm i Aeronomiya* 18(2) 224-228.

Mikhailov A. V. and G. I. Ostrovsky, 1978, "A Calculation of a Nighttime Magneto-Quiet F2 Region of the Mid-Latitude Ionosphere," *Geomagn. i Aeron.* 18 224.

Miller N. J., 1974, "The Dayside Mid-Latitude Plasma Trough," *J. Geophys. Res.* 79 3795.

Miller D. C. and J. Gibbs, 1974, "Ionospheric Analysis and Ionospheric Modeling," *AFCRL-TR-0364.*

Miller D. C. and J. Gibbs, 1974, "Ionospheric Analysis and Ionospheric Modeling," *AFCRL-TR-74-0364*

Miller D. C. and J. Gibbs, 1975, "Ionospheric Analysis and Ionospheric Modeling," *AFCRL Tech. Rept. 75-0549.*

Millman G. H., 1978a, "Ionospheric Propagation Effects on HF Backscatter Radar Measurements," *Effect of the Ionosphere on Space and Terrestrial Systems*, U.S. GPO, Washington, D.C., 211.

Millman G., 1975, "Refraction Effects on Magnetic Field Geometry and HF Propagation," *J. Atmos. Terr. Phys* 37 751-760.

Millman G., 1975, "A Simulator for Evaluating the Accuracy of Various Techniques for Total Electron Content Determination from Satellite Transmissions," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Milsom J. D., 1977, "Exact Ray-Tracing Through the Bradley/Dudeney Model Ionosphere," *Marconi Rev.* 40 206 172-95.

Minnis C. M., 1964, "Ionospheric Indices," *Advances in Radio Research, Vol. II*, J. A. Saxton (editor), Academic Press, London and New York.

Mirtov B. A. and A. G. Starkova, 1976, "Model of Daily Variations of Electron Concentration at a Height of 100-200 km in Middle Latitudes," *Geomagnetizm i Aeronomiya* 16(4) 642-646.

Mitra A. P. and D. K. Chakrabarty, 1971, "Models of Lower Ionosphere Electron Density Profiles," *Space Research XI* 2 1013-1018.

Mitra A. P. and Y. V. Somayajulu, 1979, "A Global Model of D-Region Ionization," *COSPAR Space Research* 19 269-273.

Mitra S. N. and M. Sain, "Short Term Prediction of Ionospheric Disturbances," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Miya K., K. Shimizu and T. Kojima, 1978, "Oblique-Incidence Sporadic E Propagation and Its Ionospheric Attenuation," *Radio Sci. 13 559.*

Miya K. and S. Kanaya, 1955, "Radio Propagation Prediction Considering Scattering Wave on the Earth's Surface," *Rep. Ion. Res. Japan* 9 1.

Montbriand L. E. and J. S. Belrose, 1979, "Diurnal and Seasonal Variations of the Steady State Loss Coefficient in the D Region," *J. Geophys. Res.* 84 1921.

Moo C.A., 1970, "HF-RTW Propagation Study: Prediction Scheme and Synoptic Behaviour," *Proceedings of Conference on Ionospheric Forecasting* 9.

Moorcroft D. R., 1961, "Models of Auroral Ionization," *Can J. Phys.* 39 677-715.

Morfitt D. G., 1977, "Effective Electron Density Distributions Describing VLF/LF Propagation Data," *Naval Ocean Systems Center Technical Report 141.*

Morris P. B. and M. Y. Cha, 1974, "Omega Propagation Corrections: Background and Computional Algorithm," *Report ONSOD-01-74.*

Mrazek J., 1978, "Predicting Long-Distance Short Wave Radio Connections with the Aid of a Programmable Pocket Calculator of the Texas Instruments TI-59 Type," *Slaboproudy Obz.* (Czechoslovakia) 39 7 313-19.

Muggleton L. M. and S. S. Kouris, 1968, "Relation Between Sunspot Number and the Ionospheric Index I_{F2}," *Radio Science* 3 1109-1110.

Muldrew D. B., 1965, "F-Layer Ionization Troughs Deduced From Alouette Data," *J. Geophys. Res.* 70 2635.

Muldrew D. B. and R. G. Maliphant, 1962, "Long-Distance One-Hop Ionospheric Radio Propagation," *J. Geophys. Res.* 67 1805-1815.

Murphy J. A., G. J. Baily and R. J. Moffett, 1976, "Calculated Daily Variations of O^+ and H^+ at Mid-Latitudes," *J. Atmos. Terr. Phys.* 38 351-364.

Murthy P. S. N., C. S. R. Rao and M. Sain, 1979, "Prediction of foF2 by the Monthly Ratio (MR) Method," in *Solar-Terrestrial Predictive Proceedings*, R. Donnely (editor), U.S. GPO, Washington, D.C.

Myung K. L. and J. S. Nisbet, 1975, "Propagation Predictions and Studies using a Ray Tracing Program Combined with a Theoretical Ionospheric Model," *IEEE Trans. Antennas and Propag.* AP-23 1 132-6.

Nagano I., 1980, "Full Wave Calculation of VLF Waves in Auroral Zone", *Antarctic Record* 68 203-214.

Nakagami M., 1960, "The M-Distribution: A General Formula of Intensity Distribution of Rapid Fading," *Statistical Methods in Radio Wave Propagation*, W. C. Hoffman (editor), Pergamon Press, pp. 3-36.

Narayana Rao N., 1968, "Synthesis of Oblique Ionograms for a Quasi-Linear Ionospheric Model and Spherical Earth-Ionosphere Geometry," *IEEE Trans. Antennas Propagation* AP-16 6 771.

Narayano R. N., 1968, "Bearing Deviation in HF Transionospheric Propagation. I. Exact Computations for Some Ionospheric Models with No Magnetic Field", *Radio Sci.* 3 12 1113-18.

National Research Council, 1978, "Geophysical Predictions," *National Academy of Sciences* 215.

Naval Ocean Systems Center, 1978, "The NOCS Real-Time Ionospheric Radio Propagation Assessment Capability," 119.

Nesterczuk G., J. K. Kozelsky, and J. Behuncik, 1976, "Modelling of Line-of-Sight Ionospheric Electron Density Gradients," in *The Geophysical Use of Satellite Beacon Observations*, M. Mendillo (editor), Boston University.

Nestorov G., 1972, "Exponential Model of the Ionospheric D-Region", *Geomagnetizm i Aeronimiya* 12(1) 44-53.

Nisbet J. S., O. F. Tyrnov, G. N. Zintchenko, and W. J. Ross, 1981, "Limits on the Accuracy of Correction of Trans-Ionospheric Propagation Errors by Using Ionospheric Models Based on Solar and Magnetic Indices and Local Measurements," *Radio Sci.* 16 1 127-33.

Nisbet J. S., 1970a, "On the Construction and Use of the Penn State MKI Model," *Sci Rep. 355.*

Nisbet J. S., 1970b, "Tables from the Penn State MARK I Ionospheric Model," *Sci. Rep. 362(E).*

Nisbet J. S., 1969, "On the Construction and Use of Simple Ionospheric Models", *Program and Abstracts of the URSI 1969 Spring Meeting* 32.

Nisbet J. S., 1971, "On the Construction and Use of a Simple Ionospheric Model," *Radio Sci.* 6 437.

Nishizaki R., and M. Nagayama, 1969, "Analysis of Observational Data Obtained by Alouette II. V. Comparison of foF2 from Two Observational Methods of Top-Side Sounding and Ground-Based Sounding," *J. Radio Res. Labs.* 16 227-234.

Noor-Sheikh M., E. Neske, K. Rawer, and C. Rebstock, 1978, "Comparison of Peak Electron Densities of the F2 Layer Derived from In Situ Measurements with CCIR Predictions," *Telecommun. J.* 45 225.

Obayashi T., 1959, "A Possibility of the Long Distance HF Propagation Along the Exospheric Field Aligned Ionization," *Rep. Ion. and Space Res. in Japan* 13 177.

Obayashi T. and N. Matuura, 1972, "Theoretical Model of F-Region Storm," *Solar-Terrestrial Physics/1970, Part IV* 199-211.

Oksman J. and A. Tauriainen, 1978, "On the Relative Location of the TEC Trough and the HF Backscatter Curtains." *Proc. COSPAR Symp. on Beacon Satellite Measurements of Plasmaspheric and Ionospheric Properties.*

Ondoh T. and K. Obu, 1979, "Prediction of HF Communication Disturbances by Pre-SC HF Field Increases on Polar Paths Crossing the Auroral Zone," *Solar-terrestrial Predictive Proceeding*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Orlov A. B. and I. M. Sternina, 1973, "Impedance Model of the Daytime Ionosphere," *Geomagnetizm i Aeronomiya* 13(3) 416-421.

Ossakow S. L and P. K. Chaturvedi, 1979, "Current Convective Instability in the Diffuse Aurora," *Geophys. Res. Lett.* 6 332.

Ossakow S. L and P. K. Chaturvedi, 1978, "Morphological Studies of Rising Equatorial Spread F Bubbles," *J. Geophys. Res.* 83 2085.

Ossakow S. L., 1974, "Research at NRL on Theoretical and Numerical Simulation Studies of Ionospheric Irregularities," *NRL Reports of Progress.*

Ossakow S. L., A. J. Scannapieco, S. R. Goldman, D. L. Book, and B. E. McDonald, 1975, "Theoretical and Numerical Simulation Studies of Ionospheric Inhomogeneities Produced by Plasma Clouds," *Ionospheric Effects Symposium*, Washington, D.C.

Ossakow S. L., 1979, "Ionospheric Irregularities," *Rev. Geophys. Space Phys.* 17 521.

Ott E., 1978, "Theory of Rayleigh-Taylor Bubbles in the Equatorial Ionosphere," *J. Geophys. Res.* 83 2066.

Oyinloye J. O., 1979, "Prediction of Radio Wave Absorption in the Ionosphere," *Solar-terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Pappert R. A., W. F. Moler, and J. A. Ferguson, 1980, "A Numerical Study of Satellite Reception of VLF Signals Using Wave Guide Concepts," *Radio Sci.* 15 517.

Pappert R. A., and W. F. Moler, 1978, "A Theoretical Study of ELF Normal Mode Reflection and Absorption Produced by Nighttime Ionospheres," *J. Atmos. Terr. Phys.* 40 1031.

Park C. G., D. L. Carpenter, and D. B. Wiggin, 1978, "Electron Density in the Plasmasphere: Whistler Data on Solar Cycle, Annual, and Diurnal Variations," *J. Geophys. Res.* 83 3137.

Paul A. K., 1978, "Temporal and Spatial Distribution of the Spectral Components of foF2," *J. Atmos. Terr. Phys.* 40 135.

Paul A. K., T. L. Gulyaeva, L. F. McNamara, J. E. Titheridge, and J. W. Wright, 1978, "Analysis of Numerical Ionograms, 3, The Valley Problem, *Ionospheric Predictions*, Series X X8 1-22.

Paul H. H, D. McKinnis, J. Wright, 1967, "Ionospheric Electron-Density Profiles with Continuous Gradients and Underlying Ionization Correction," *Radio Science 2* 10.

Pedersen P. O., 1929, "Wireless Echoes of Long Delay," *Proc. IRE* 17 1750-1785.

Petrie L. E. and E. E. Stevens, 1965, "An F1 Layer MUF Prediction System for Northern Latitudes," *IEEE Trans. Ant. Prop.* AP-13 542-546.

Pfitzer K. A., S. J. Scotti, and W. P. Olson, 1981, "A Semi-Empirical Model of the Ionospheric Electron Denisty," in *Effect of the Ionosphere on Radiowave Systems*, J.M. Goodman (editor-in-chief), US GPO, Washington, D.C.

Philbrick C. R., 1981, "Empirical F-region Model Development Based on S3-1 Satellite Measurements," in *Effect of the Ionosphere on Rediowave Systems*, J.M. Goodman (editor-in-chief), US GPO, Washington, D.C.

Pickering L. W., 1975, "The Calculation of Ionospheric Doppler Spread on HF Communication Channels," *IEEE Trans. Communications, COM-23* 5 526-537.

Picquenard A. A. E. and E. R. dePaula, 1979, "A Simplified Computer Method for Long-Term Calculation of HF Sky-Wave Circuits," in *Solar-Terrestrial Predictions Proceedings*, R.F. Donnelly (editor), U.S. Government Printing Office, Washington, D.C., 4 D2-41.

Piggott W.R., 1970, "The Use of Satellite Data for Prediction Purposes," *Proceedings of Conference on Ionospheric Forecasting* 17.

Piggott W.R., 1975, "High Latitude Supplement to URSI Handbook of Ionogram Interpretation and Prediction," *World Data Center A for Solar Terrestrial Physics, Report UAG-50.*

Piggott W.R., 1969, "The Acquisition and Use of Ionospheric Data for Prediction and Other Practical Applications," *Telecommunication Journal* 36 273-279.

Piggott W. R., 1970, "The Use of Satellite Data for Prediction Purposes, in Ionospheric Forecasting," *AGARD Conference Proceedings No. 49.*

Piggott W. R. and K. Rawer, 1972, "URSI Handbook of Ionogram Interpretation and Reduction (2nd Ed.)," *World Data Center A for Solar-Terrestrial Physics. Report UAG 23.*

Pike C. P., 1972, "Modelling the Arctic F-layer," *Air Force Surveys in Geophsics* 241 29-45.

Pike C. P., 1976, "An Analytical Model of the Main F-Layer Trough," *AFGL-TR-76-0098.*

Pike C. P. (editor), 1975, "Defense Meteorological Satellite Program Auroral Ionospheric Interpretation Guide," *Air Force Surveys in Geophysics* 306 NTIS AD-AO13165.

Pisacane V. L., M. M. Feen, and M. Sturmanis, 1972, "Prediction Techniques for the Effect of the Ionosphere on Pseudo Ranging from Synchronous Altitude Satellites," *Applied Physics Laboratory* SAMSO TR-72-22, DDC AD-749486.

Poletti-Liuzzi D. A., K. C. Yeh, and C.H. Liu, "Simulation and Measurement of the Plasmaspheric Electron Content," *The Geophysical Use of Satellite Beacon Observations*, M. Mendillo (editor), Boston University.

Polyakov V. M., M. A. Koen, G. V. Khazanov, 1975, "A Nonstationary Model of the Density and Temperature Distributions of Charged Particles Along Geomagnetic Field Lines," *IZV. VUZ Radiofiz. (USSR)* 18 4 510-15.

Polyakov V. M., 1978, "Semiempirical Model of the Ionosphere in the Steady-State and Nonsteady-State Approximations," *Geomagnetizm i Aeronomiya*, Moscow 18(3) 531-533.

Pope J. H., 1974, "High Latitude Ionospheric Irregularity Model," *Radio Sci.* 9 675.

Pope J. H., 1974, "Ionospheric Scintillation Predictions for the Geostationary Satellites Goes and ATS-F," *Indian J. Radio and Space Phys.* 3 1 55-61.

Pope J. H., 1974, "High Latitude Ionospheric Irregularity Model," *Radio Sci.* 9 675-682.

Potapova N. I., 1971, "Prediction of Geometrical Parameters for *N(h)*-Profiles and *hf*-Characteristics of the Quiet and Disturbed Ionosphere. II. Day-to-Day Variations of *N(h)* and *hf* Parameters. Published in the Collection "Ionospheric Disturbances and Their Influence on Radiocommunications," Nauka, 117, Moscow (in Russian).

Price G. H., 1973, "High-Frequency Radio-Wave Propagation Through Plane-Stratified Ionospheric Models," *Radio Science* 8 (2) 133-138

Price G. H., 1972, "Analytic Ray Solutions for High-Frequency Radio-Wave Propagation Through Plane Stratified ionosphere Models," *Radio Science* 7 (4) 449-455.

Price R. and P. E. Green, 1958, "A Communication Technique for Multipath Channels," *Proc. IRE* 46 555-570.

Prikner K., 1980, "ULF-Wave Diagnostics of a Mid-Geomagnetic Latitude Model of the Ionosphere," *Geophys. Inst.*, Czechoslovakian Acad. of Sci., Prague 24 (2) 173-190.

Probst S. E., 1970, "Comments on the Nature of HF Ionospheric Predictions Required for Use in the DCA and the DCS," *Proceedings of Conference on Ionospheric Forecasting*, V. Agy (editor), pp 3.

Probst S. E., 1968, "The CURTS Concept and Current State of Development," *Ionospheric Radio Communications*, K. Folkestad, (editor), Plenum Press, New York, pp. 370-379.

Raitt W. J., R. W. Schunk, and J. J. Sojka, 1980, "Modelling the High Latitude Ionosphere," *Proceedings of the AGARD/NATO Symposium on The Physical Basis of the Ionosphere in the Solar-Terrestrial System*, Naples, Italy.

Ramakrishnan S., D. Bilitza, and H. Thiemann, 1979, "Limitations of the IRI-78 Model," presented at COSPAR General Assembly, Bangalore, India.

Ramsey A. C., 1970, "A Model of Ionospheric Total Electron Content," *Air Weather Service, Tech. Report* 234.

Rao N. N., M. Y. Youakim, and K. C. Yeh, 1971, "Feasibility Study of Correcting for the Excess Time Delay of Transionospheric Navigational Varying Signals," Tech. Report 43 (SAMSO-TR-71-163) Univ. of Ill., Ionospheric Physics Lab, Urbana, Ill.

Rao N. N., 1968b, "Bearing Deviation in HF Transionospheric Propagation. I. Exact Computations for Some Ionospheric Models with no Magnetic Field," *Radio Science* 3 1113-1118.

Rao N. N., 1968c, "Bearing Deviation in HF Transionospheric Propagation. II. Application of Exact Computations," *Radio Science* 3 1119-1123.

Rao N. N., M. Y. Youakim, and K. C. Yeh, 1971, "Feasibility Study of Correcting for the Excess Time Delay of Transionospheric Navigational Ranging Signals," SAMSO TR-71-163, DDC AD-729797, University of Illinois, Urbana, Ill.

Rao N. N. and R. I. Beckwith, 1974, "Prediction of Azimuthal Angle of Arrival of HF Waves During the Sunrise Period," *Radio Science* 9 617-620.

Rao C. S. R. and M. Sain, 1965, "Prediction of Critical Frequency of F2-layer," *J. Inst. of Telecommunication Engineers* 2(8) 271-281.

Rao N. N., 1968a, "Ray-Tracing Investigation of Direction of Arrival Observation of HF Radio Waves," *Radio Science* 3 796-802.

Rastogi R. G., 1980, "Seasonal and Solar Cycle Variations of Equatorial Spread F in the American Zone," *J. Atmos. Terr. Phys.* 42 593.

Rastogi R. G., 1959, "The Diurnal Development of the Anomalous Equatorial Belt in the F2-region of the Ionosphere," *J. Geophys. Res.* 64 727-732.

Rawer K., 1952, "Calculation of Sky-wave Field Strength," *Wireless Engineer* 287-300.

Rawer K., D. Bilitza, and S. Ramakrishnan, 1978a, "Goals and Status of the International Reference Ionosphere," *Rev. Geophys. Space Phys.* 16 177.

Rawer K., D. Bilitza, S. Ramakrishnan, and M. N. or Sheikh, 1978b, "Intentions and Build-up of the International Reference Ionosphere," in *Operational Modelling of the Aerospace Propagation Environment* AGARD-CPP-238 6.1-6.10.

Rawer K., 1975, "Intercomparison of Different Measuring Techniques in the Upper Atmosphere," *The International Reference Ionosphere* Space Res. 15 295-320.

Rawer K., D. Bilitza, S. Ramakrishnan, 1978, "Goals and Status of the International Reference Ionosphere," *Reviews of Geophysics and Space Physics* 16 (2) 177-181.

Rawer K., S. Ramakrishnan, and D. Bilitza, 1978b, "International Reference Ionosphere 1978," URSI, Av. Albert Lancaster 32, B-1180 Brussels, Belgium.

Rawer K., S. Ramakrishnan, and D. Bilitza, 1978c, "International Reference Ionosphere 1978," *International Union of Radio Science* B-1180, Brussels.

Rawer K. (editor), 1974, "Methods of Measurements and Results of Lower Ionosphere Structure," Akademie Verlag, Berlin.

Rawer K., 1977, "Mid and High Latitude Reference Ionosphere," in *Dynamical and Chemical Coupling of Neutral and Ionized Atmosphere*, B. Grandal and J.A. Holtel (editors), D. Reidel Pub Co Dordrecht Holland, pp. 129-144.

Rawer K., 1977, "Mid- and High-Latitude Reference Ionosphere," *Dynamical and Chemical Coupling between the Neutral and Ionized Atmosphere: Proceedings of the NATO Advanced Study Institute*, B. Grandal and J. A. Holtet (editors), D. Reidel Publ. Co., Dordrecht, Holland, pp. 129-143.

Rawer K., S. Ramakrishnan, and D. Bilitza, 1975, "Preliminary Reference Profiles for Electron and Ion Densities and Temperatures Proposed for the International Reference Ionosphere," *Sci. Rep. W.B.2*, Inst. fur Phys. Weltraumforsch, Freiburg, Federal Republic of Germany.

Rawer K., S. Ramakrishnan, and D. Bilitza, 1975, "Preliminary Reference Profiles of Elektron and Ion Densities and Temperatures, Rept. IPW-W82," Institut fur Physikalische Weltraumforschung, Freiburg, F.R.G.

Rawer K, E. Harnischmacher, and R. Eyfrig, 1980, "The Day-by-Day Variability of the Ionospheric Peak Density, The Physical Basis of the Ionosphere in the Solar-Terrestrial System," *AGARD Conf. Proc.* 295 34-1.

Rawer K., 1975, "The Historical Development of Forecasting Methods for Ionospheric Propagation of HF Waves," *Ra... Science* 10 669.

Rawer K., 1978, "World-Wide Description of Ionospheric Topside Electron Density," *Space Research XVIII* 229-231

Rawer K., C. Rebstock, N. Sheikh, D. Bilitza, and E. Neske, 1977, "Worldwide Description of Ionospheric Topside Electron Density," Paper Presented at *20th Plenary Meeting of COSPAR Comm. on Space Res.*, Tel Aviv.
Reddy B. M., 1979, "Ionosphere-Reflected Propagation," in *Solar-Terrestrial Predictions Proceedings*, R. Donnelly (editor), U.S. GPO Washington, D.C., p. 203.
Reynolds D. A., 1970, "Application of Short Term Propagation Predictions and Radio Disturbances Warnings within the Canadian Forces Communication System," *Proceedings of Conference on Ionospheric Forecasting*, V. Agy (editors), pp. 8.
Rice S. O., 1958, "Distribution of the Duration of Fades in Radio Transmission: Gaussian Noise Model," *BSTJ* 37 581.
Richmond A. D., 1972, "Numerical Model of the Equatorial Electrojet," United States Air Force, Cambridge Research Labs., Bedford, Ma. *Environmental Research Papers* 421 62.
Rino C. L., 1979a, "A Power Law Phase Screen Model for Ionospheric Scintillation, 1, Weak Scatter," *Radio Sci.* 14 1135.
Rimo C. L., C. H. Dawson, R. C. Livingston, and J. Petriceks, 1978, "The Ionospheric Limitation to Coherent Integration in Transionospheric Raders," in *Effect of the Ionosphere on Space and Terrestrial Systems*, J.M. Goodman (editor), U.S. GPO Washington, D.C.
Rino C. L., 1979, "A Power Law Phase Screen Model for Ionospheric Scintillation 1. Weak Scatter," *Radio Sci.* 14 (6) 1135-45.
Rino C. L., 1979b, "A Power Law Phase Screen Model for Ionospheric Scintillation, 2 Strong Scatter," *Radio Sci.* 14 1147.
Rino C. L. and S. J. Matthews, 1980, "On the Morphology of Auroral Zone Radio Wave Scintillation," *J. Geophys. Res.* 85 4139.
Rino C. L., 1975, "Some Unique Features of the Transionospheric Channel," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO Washington, D.C.
Rishbeth H., 1971, "Use of F Layer Theory in Ionospheric Predictions," *Proc. Inst. Elec. Eng. (GB)* 118 (10) 1323-6.
Rishbeth H., 1971, "The Use of F Layer Theory in Ionospheric Predictions," *Colloquium on Satellite, Rocket and Thomson Scatter Data and its Application to Communications* 6.
Rishbeth H. and D. M. Kelley, 1971, "Maps of the Vertical F-layer Drifts Caused by Horizontal Winds at Mid-latitudes," *J. Atmos. Terr. Phys.* 33 539-545.
Rodionov Ya. S. and V. S. Gubenko, Oct. 1968, "The Potentialities of Short-Term Ionospheric Forecasting for Communications Purposes," *Elektrosvyaz* 10 20-3.
Rose R. B., J. R. Hill, and M. P. Bleiweiss, 1974, "Sudden Ionospheric Disturbance Grid," *Naval Electronics Laboratory Center Technical Report 1938, NTIS* A006567.
Rose R. B., D. G. Morfitt, and M. P. Bleiweiss, 1971, "System Performance Degradation Due to Varying Solar Emission Activity: SOLRAD Applications Study, Task II," *Naval Electronics Laboratory Center Technical Report 174, NTIS* 888493L.
Rosich R. K. and W. B. Jones, 1973, "The Numerical Representation of the Critical Frequency of the F1 Region of the Ionosphere," Office of Telecommunications, Report 73-22, U.S. Dept. of Commerce.
Rothmuller I. G., 1978, Real Time Propagation Assessment: Initial Test Results *Effects of the Ionosphere on Space and Terrestrial Systems*, U.S. GPO, Washington, D.C., 380.
Rothmuller I. J., 1978, "Real-Time Propagation Assessment" in *AGARD Proc.*, AGARD Conf. preprint AGARD-CPP-238.
Rush C. M. and D. Miller, 1973, "A Three Dimensional Ionospheric Model Using Observed Ionospheric Parameters," *Rep. AFCRL-TR-73-0567*, Cambridge Res. Lab., Hanscom Air Force Base, Ma.
Rush C. M., 1978, "Ionospheric Predictions: Methods and Results," *Nat. Telecommunications and Information Administration*, H. Soicher (editor), US Dept. of Commerce, Boulder, CO.
Rush C. M., and D. Miller, 1973, "Three-dimensional Ionospheric Model Using Observed Ionospheric Parameters," United States Air Force, Cambridge Research Labs., Bedford, Ma. *Environmental Research Papers* 455 55.
Rush C. M., 1976, "An Ionospheric Observation Network for Use in Short-term Propagation Predictions," *Telecommunication Journal* (8) 544-549.
Rush C. M., 1977, "Ionospheric Forecasting," *7th Technical Exchange Conference Proceedings* 203-207.
Rush C. M., 1972, "Improvements in Ionospheric Forecasting Capability," *Environmental Research Papers* 387 56.
Rush C. M., 1975, "Limitations of Mapping Techniques to Predicting Total Electron Control at a Distant Point," in *Effect of the Ionosphere on Space Systems and Communications*, J.M. Goodman (editor), U.S. GPO, Washington, D.C.
Rush C. M. and E. Ziemba, 1978, "On the Usefulness of Topside HF Noise Measurements in Determining foF2," *J. Atmos. Terr. Phys.* 40 1073.
Rush C. M. and J. Gibbs, 1973, "Predicting the Day-to-Day Variability of the Mid-Latitude Ionosphere for Application to HF Propagation Predictions," *Air Force Surveys in Geophysics* 268 19.
Rush C., 1979, "Report of the Mid- and Low-Latitude E and F Region Working Group," in *Solar-terrestrial Predictions Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C. p. 562.
Rush C. M. and D. Miller, 1972, "Some Aspects of the Day-to-Day Variability of the Equatorial Anomaly; American and Japanese Sectors," *Radio Sci.* 7 1085-1094.
Rush C. M., D. Miller, and J. Gibbs, 1974, "The Relative Daily Variability of foF2 and hmF2 and Their Implications for HF Radio Propagation," *Radio Science* 9 749-756.
Rycroft M. J. and J. O. Thomas, 1970, "The Magnetospheric Plasmapause and the Electron Density Trough at the Alouette I Orbit," *Planet. Space Sci.* 18 65.

Sailors D., 1981, "An Empirical Model for the Probability Distribution of the Lowest Observed Frequency," in *Effect of the Ionosphere on Radiowave Systems*, edited by J. M. Goodman, F. D. Clarke, and J. Aarons, U.S. GPO, Washington, D.C.
Sailors D. B., C. P. Kugel, and G. W. Haydon, 1977, "Predicting the Compatibility of High Frequency Sky-Wave Communication Systems," *IEEE Trans. Electromagn. Compat.* EMC-19 3 Pt. 2 332-43.

Sailors D. B. and J. R. Hill, 1977, "Simulation and Measurement of the HF Channel," *Naval Ocean Systems Center Tech. Rept. 111*, NTIS A043384.

Salaman R. K., 1970, "Can the Communicator Obtain Useful Ionospheric Forecasts?" *Proceedings of Conference of Inospheric Forecasting*, V Agy (Editor), p. 2.

Salaman R. K., 1970, "Operationally Oriented Telecommunication Forecast Service," *Proceedings of Conference on Ionospheric Forecasting*, V. Agy (editor), p. 13.

Samuel J. C. and P. A. Bradley, 1975, "A New Form of Representation of the Diurnal and Solar-Cycle Variations of Ionospheric Absorption," *J. Atmosph. Terr. Phys.* 37 131.

Sazhin V. I. and M. V. Tinin, 1975, "Long-Distance Propagation by Means of the Pedersen-Ray," *Geomagnetism and Aeronomy* 15 564-567.

Sato T., 1980, "Morphological Features of the Winter Anomaly in Ionospheric Absorption of Radio Waves at Middle Latitudes," *J. Geophys. Res.* 85 197.

Schlegel K., 1973, "Monte Carlo Simulation of a Model Ionosphere, Pt. 2, Energy Flow and Energy Dissipation," *Journal of Atmospheric and Terrestrial Physics* 35(3) 415-424.

Schunk R. W., W. J. Raitt, and J. J. Sojka, 1981, "High Latitude Ionospheric Model: First Step Towards a Predictive Capability," in *Effect of the Ionospheric on Radiowave Systems*, J. M. Goodman (editor-in-chief), U.S. GPO, Washington, D.C.

Sehgal O. P. and H. O. Agrawal, 1979, "A Method of Predicting Skywave Field Strength in HF Bands in Tropical Zones," *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Shapiero B. S., 1970, "Inter-Relation of the Parameters of the F2 and F1 Regions and Prediction of the Daytime N(h) Profiles and h'f Characteristics," *Geomagnetism and Aeronomy* 344.

Shapiero B. S., 1973, "Predicting the Geometric Parameters of the N(h) Profiles and h'f Characteristics of the Quiet and Disturbed Ionosphere, Pt. 1, Regular Variations of the N(h) and h'f Geometric Parameters," *United States National Aeronautics and Space Administration, Technical Translation F-746*, 132-154.

Shapiero B. S., T. A. Anufrieva, A. A. Freison, and T. A. Vinnikova, 1971, "Prediction of Geometrical Parameters for N(h) Profiles and h'f Characteristics of the Quiet and Disturbed Ionosphere. I. Regular Variations of N(h) and h'f Geometrical Parameters," *Ionospheric Disturbances and Their Influence on Radiocommunications* 100.

Shapiero B. S. and V. M. Shashounkina, 1971, "Prediction N(h) Profiles and h'f Characteristics of the Quiet and Disturbed F-Region. III. N(h) and h'f Parameters During Disturbances," *Ionospheric Disturbances and their Influence on Radiocommunications* 135.

Shapiero B. S., N. I. Potapova, T. A. Anufrieva, A. A. Freison, and V. M. Shashounkina, 1971, "Prediction of N(h) Profiles and h'f Characteristics of Quiet and Disturbed F-Region. IV. Variations of the Angles of Arrival (A) and the *Hop Distance (D)*," *Ionospheric Disturbances and Their Influence on Radiocommunications* 146.

Shapiero B. S., 1970, "Association of F2- and F1-layer Parameters and Forecasting of Daytime (N(h)-profiles and h'f-Characteristics," *Geomagnetizm i Aeronomiya* 10(2) 344-346.

Shapiero B. S., 1960, "To the Question of Working Out the Predictions of Geometrical Parameters (hm and ym) and h'f Characteristics of the Ionosphere," *Academy of Sciences* 17/7 216-239.

Sharma R. P and E. J. Hewens, 1976, "A Study of the Equatorial Anomaly at American Longitudes During Sunspot Minimum," *J. Atmos. Terr. Phys.* 38 475-484.

Shaver H. N., B. C. Tupper, and J. B. Lomax, 1967, "Evaluation of a *Gaussian HF Channel Model*," *IEEE Trans. Commun. Technol.* COM-15 74-88.

Shchuka T. I., 1978, "Dependence of Global-Time-Distribution of Auroral Absorption on Magnetic Activity," *Trudy AANII* 350 88.

Shearman E. D. R., 1961, "An Investigation of the Usefulness of Back-Scatter Sounding in the Operation of High Frequency Broadcasting Services," *Proc. IEEE* 108B 361.

Sheikh N., K. Rebstock, and D. Bilitza, 1978, "Computer Programs Related with Numerical Mapping After CCIR-Report 340, IPW-WB9," *Institut f. Physikalische Weltraumforschung*.

Shlionsky A. G., 1979, "Prediction of Waveguide Propagation of Radio Waves Using the Extremal-Parametric Method Based on Predicted Ionospheric Parameters," *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Sidorov N. A., 1971, "Stability of the Dynamic Model of the F-Region of the Ionosphere," *Geomagnetizm i Aeronomiya* 11(6) 1084-1085.

Simon P., 1970, "Contribution of the Solar Activity Forecast to the Short Term Forecast of the Ionosphere," *Proceedings of Conference on Ionospheric Forecasting*, V. Agy (editor), p. 1.

Singer W., J. Taubenheim, and J. Bremmer, 1980, "Test of IRI Lower Ionosphere Models by Comparison with Radio Propagation Data," *Journal of Atmospheric and Terrestrial Physics* 42(3) 241-248.

Singleton D. G., 1977, "The Reconciliation of An F-Region Irregularity Model with Sunspot Cycle Variations in Spread-F Occurrence," *Radio Sci.* 12 1 107-18.

Singleton D. G., 1975, "Empirical Model of Global Spread-F Occurrence," *Journal of Atmospheric and Terrestrial Physics* 37(12) 1535-1544.

Singleton D. G., 1979a, "An Improved Ionospheric Irregularity Model" in *Solar-Terrestrial Predictions Proceedings*, Vol. 4 edited by R. F. Donnelly, U.S. Government Printing Office, Washington, D.C., p. D1-1.

Singleton D. G., 1978, "An Improved Ionospheric Irregularity Model," *ERL-46-TR, Electronics Res. Lab.*, Dep. of Defence, Australia.

Singleton D. G., 1960, "The Geomorphology of Spread F," *J. Geophys. Res.* 65 3615.

Singleton D. G., 1979b, "Predicting Transionospheric Propagation Conditions" in *Solar-Terrestrial Predictions Proceedings*, R. F. Donnelly (editor), U.S. Government Printing Office, Washington, D.C., Vol. 4, p. D1-16.

Slutz R. J., T. N. Gautier, and M. Leftin, 1969, "Short-Term Radio Propagation Forecasts in Southeast Asia," *ESSA Tech. Rep.* ERL-97-ITS-72.

Smith E. K., 1978, "Temperate Zone Sporadic E maps (foEs > 7 MHz)," *Radio Sci.* 13 571.

Smith P. A., 1968, "An Ionospheric Prediction System Based on the Index I_{F2}," *J. Atmos. Terr. Phys.* 30 177-185.

Snyder A. L., Jr., 1979, "Ionospheric and Magnetospheric Modelling for Air Force Applications" in *Quantitative Modeling of Magnetospheric Processes*, edited by W. P. Olson, American Geophysical Union, Washington, D.C.

Synder A. L. and J. Buchan, 1977, "Environmental Studies Relating to Ionospheric Effects on Dept. of Defense Systems," AIAA 15th Meeting, Los Angeles, CA.

Synder F. P. and J. A. Ferguson, 1981, "The Use of the International Reference Ionosphere (IRI-78) Models for Calculating Long Path Fields at VLF" in *Effect of the Ionosphere on Radiowave Systems*, J. M. Goodman (editor-in-chief), U.S. GPO, Washington, D.C.

Soicher H., 1976, "Comparative Ionospheric and Plasmaspheric Electron Contents from Three World Regions," *Nature* 264 46-48.

Soicher H., 1979, "Prediction of Transionospheric Signal Time Delays at Widely Separate Locations Using Correlative Techniques," *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Sojka J. J., J. C. Foster, W. J. Raitt, R. W. Schunk, and J. R. Doupnik, 1980a, "High-Latitude Convection: Comparison of a Simple Model with Incoherent Scatter Observations," *J. Geophys. Res.* 85 703-709.

Sojka J. J., W. J. Raitt, and R. W. Schunk, 1980b, "A Comparison of Model Predictions for Plasma Convection in the Northern and Southern Polar Regions," *J. Geophys. Res.* 85 1762-1768.

Somayajulu Y. V. and A. B. Ghosh, 1976, "Ionospheric Refraction Errors in Satellite Tracking and Navigation in Low Latitudes" in *The Geophysical Use of Satellite Beacon Observations*, M. Mendillo (editor), Boston University

Somayajulu Y. V. and A. B. Ghosh, 1978, "Modelling the Low Latitude Ionosphere" in *Effect of the Ionosphere on Space and Terrestrial Systems*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Stein S., 1958, "The Role of Ionospheric Layer Tilts in Long-Range High Frequency Radio Propagation," *J. Geophys. Res.* 63 217-241.

Sternina I. M., 1975, "Impedance Model of the Daytime Ionosphere in the Case of an Electron Concentration Profile of an Arbitrary Form," *Geomagnetizm i Aeronomiya* 15(4) 651-654.

Stevens E. E., 1968b, "The CHEC Sounding System," *Ionospheric Radio Communications*, K. Folkestad (editor), Plenum Press, New York, pp. 359-369.

Stevens E. E., 1968a, "The Significance of Sporadic E Propagation in Determining the MUF," *Ionospheric Radio Communications*, K. Folkestad (editor), Plenum Press, New York, pp. 289-293.

Stonehocker G. H., 1970, Advanced telecommunication Forecasting Technique, Paper 27 in AGARD Conf. Proc. No. 49," *Ionospheric Forecasting*, V. Agy (editor).

Suvorov V. V., 1979, "Empirical Model for Calculating Parameters of the F2-Layer," *Geomagnetizm i Aeronomiya* 19(3) 444-448.

Swanson E. R. and R. P. Brown, 1972, "Omega Propagation Prediction Primer," *Technical Note 2101*, Naval Electronics Laboratory Center.

Swanson E. R., 1972, "VLF Phase Prediction, VLF-Propagation," *Proc VLF-Symposium*, Report 7201, Norwegian Institute of Cosmic Physics 8.1 to 8.36.

Swider W., 1981, "Modelling the C and D Regions" in *Effect of the Ionosphere on Radiowave Systems*, edited by J. M. Goodman, F. D. Clarke, and J. Aarons, U.S. GPO, Washington, D.C.

Swider W., T. J. Keneshea, and C. I. Foley, 1978, An SPE-Distributed D Region Model," *Planet. Space Sci. 26 883*.

Szuszczewicz E. P., J. C. Holmes, and D. N. Walker, 1978, "Rocket Observations of Ionospheric Irregularities: Implications for HF Modelling," in *Effect of the Ionosphere on Space and Terrestrial Systems*, J. M. Goodman (editor), U.S. GPO, Washington, D.C., 220.

Tao K., 1965, "Worldwide Maps of the Occurrence Percentage of Spread-F in Years of High and Low Sunspot Numbers," *J. Radio Res. Lab.* 12 317.

Tascione T. F., T. W. Flattery, V. G. Patterson, J. A. Secan, and J. W. Taylor, Jr., 1978, "Ionospheric Modelling at AFGWC," in *IES '78*, J. M. Goodman (editor).

Tascione T. F., T. W. Flattery, V. G. Patterson, J. A. Secan, and J. W. Taylor, 1979, "Ionospheric Modeling at Air Force Global Weather Central. in *Solar-Terrestrial Predictions Proceedings*, R. F. Donnelly (editor), U.S. Government Printing Office, Washington, D.C., vol 1, p. 367.

Tascione T. F., T. W. Flattery, V. G. Patterson, J. A. Secan, and J. W. Taylor, Jr. 1979, "Ionospheric Modelling at Air Force Global Weather Central," Ref. B, 367.

Taylor G. N., 1971, "Application of Incoherent Scatter Data to Communications," *Colloquium on Satellite, Rocket and Thomson Scatter Data and its Application to Communications* 4.

Taylor Harry A., Jr. 1978, "Signature of H. SUPER +. in the Equatorial Anomaly: an Empirical Model," *Reviews of Geophysics and Space Physics* 16 2 267-277.

Thomas L., 1974, "The Temporal and Geographical Variations of D-Region Electron Concentrations," *Rawer* 153-167.

Thompson R. L. and J. A. Secan, 1979, "Geophysical Forecasting at AFGWC," in *Solar-Terrestrial Predictions Proceedings*, R. F. Donnelly (editor), U.S. Government Printing Office, Washington, D.C., vol. 1, p. 350.

Thompson R. L., 1978, "User Requirements of Aerospace Propagation — Environment Modeling and Forecasting," *Proceedings of the AGARD Symposium on Operational Modeling of the Aerospace Propagation Environment* NATO-AGARD Proc., Ottowa.

Thomas L., 1979, "A Study of the Enhanced Electron Concentrations in the Mid-Latitude D Region on Winter Days in Terms of the Positive Ion Chemistry," *J. Geomagn. Geoelectr.* 31 567.

Thrane E. V., and P. A. Bradley, 1981, "High Frequency Sky-Wave Prediction Methods and Observational Data for High-Latitude Communication Circuits," *Second International Conference on Antennas and Propagation* 2/258-62.

Thrane E. V., D. K. Chakrabarty, S. D. Deshpande, R. H. Doherty, J. B. Gregory, J. K. Hargreaves, J. Lastovicka, P. Morris, W. R. Piggott, J. B. Reagan, W. A. Schlueter, E. Swanson, and W. Swider, 1979, "D Region Predictions," in *Solar-Terrestrial Predictions Proceedings*, F. R. Donnelly (editor), U.S. GPO, Washington, D.C., 573.

Titheridge J. E., 1958, "Variations in the Direction of Arrival of High-Frequency Radio Waves," *J. Atmos. Terr. Phys.* 13 17-25

Toman K., and D. C. Miller, 1977, "Computation Study of Long-Range High-Frequency Ionospheric Ducting," *Radio Science* 12 467-476.

Toman K., 1979, "High-Frequency Ionospheric Ducting — A Review," *Radio Sci.* 14 447.

Tran A., and C. Polk, 1979, "Schumann Resonances and Electrical Conductivity of the Atmosphere and Lower Ionosphere, II. Evaluation of Conductivity Profiles from Experimental Schumann Resonance Data," *J. Atmos. Terr. Phys.* 41 1249.

Trost T. F., 1979, "Electron Concentrations in the E- and Upper D-region at Arecibo," *J. Geophys. Res.* 84 2736.

Tsedilina Y. Y., 1975, "Round-the-World Radio Wave Propagation in Ionospheric Wave Ducts," *Geomagnetism and Aeronomy* 15 371-374.

Tulunay Y. K. and J. M Grebowsky, 1978, "The Noon and Midnight Mid-Latitude Trough as Seen by Ariel 4," *J. Atmos. Terr. Phys.* 40 845.

Turin G. L., 1956, "Communication Through Noisy, Random-Multipath Channels," *IRE Nat. Conv. Record* Part 4 154.

Turner J. F., 1979, "Grafex Predictions," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO Washington, D.C.

Turunen T. and J. Oksman, 1979, "On the Relative Location of the Plasmapause and the HF Backscatter Curtains," *J. Atmos. Terr. Phys.* 41 345.

Tushentsova I. A., D. I. Fishchuk, and Ye. Ye. Tsedilina, 1975, "Global Distribution of Short-Wave Absorption in the Ionosphere," *Izvestiya VUZ, Radiofizika* 18 9 1279-1287.

Tushentsova I. A., D. I. Fishchuk, and Y. Y. Tsedilina, 1975, "Investigation of the Global Properties of Ionospheric Wave Ducts II," *Geomagnetism and Aeronomy* 15 62-66.

Tveten L. H., 1961, "Ionospheric Motions Observed with High-Frequency Back-Scatter Sounders," *NBS Journ. of Research* 65-D 115-127.

Tveten L. H. and R. D. Hunsucker, 1969, "Remote Sensing of the Terrestrial Environment with an HF Radio High-Resolution Azimuth and Elevation Scan System," *Proc. IEEE* 57 487-493.

Ulaszek S. J., C. H. Liu and K. C. Yeh, 1975, "Frequency Correlations and Coherent Bandwidth of Transionospheric Signals," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Unwin R. S., 1967, "The Morphology of the Radio Aurora at Sunspot Maximum: I Diurnal and Seasonal Variations," *J. Atmos. Terr. Phys.* 28 1167-1181.

Velinov P. I., "Generalized Exponential Model of Electron Concentration Profiles in Low Ionospheres," *Bolgarskaya Akademiya Nauk.* 29(12) 1757-1761.

Villard O. G. and A. M. Peterson, 1952a, "Scatter-Sounding a Technique for Study of the Ionosphere at a Distance," *Trans. IRE* PGAP-3 186-201.

Vlasov M. N., "Fundamentals of the Physical Forecast of Ionospheric Plasma," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (*editor*), *U.S. GPO, Washington, D.C.*

Vlasov M. N. and A. G. Kolesnik, 1979, "Self-Consistent Model of the Ionospheric Plasma and the Hydrodynamic Forecast," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C.

Vondrak R., R. Tsunoda, E. Hatfield, P. Perreault and G. Smith, 1978, "Chatanika Model of the High-Latitude Ionosphere," in *Effect of the Ionosphere on Space and Terrestrial System*, J. M. Goodman (editor), U.S. GPO, Washington, D.C., 130.

Vondrak R. R., G. Smith, V. E. Hatfield, R. T. Tsunoda, V. R. Frank and P. D. Perreault, 1977, "Chatanika Model of the High-Latitude Ionosphere for Application to HF Propagation Prediction," *Tech. Rep. RADC-TR-78-7.*

Vondrak R. R., et al., 1979, "Magnetosphere-Ionosphere Interactions," in *Solar-Terrestrial Predictions Proceedings*, R. Donnelly (editor), U.S. GPO, Washington, D.C., p. 476.

von Flotow C. S., 1978, "Ionospheric Forecasting at Air Force Global Weather Central," in *Effect of the Ionosphere on Space and Terrestrial Systems*, J. M. Goodman (editor), U.S. GPO-0-277-172.

Vovk V. Y., I. N. Kosterin and V. B. Smirnov, 1978, "Investigation of Radio Wave Propagation Modes on Polar Paths in Oblique Ionospheric Sounding," *Trudy AANII, L.* 351 20.

Wagner R. A., 1972, "Modelling the Auroral E-Layer," *Geophysics* 241 9-20.

Wait J. R. and K. P. Spies, 1964, "Characteristics of the Earth-Ionosphere Waveguide for VLF Radiowaves," *NBS Technical Note 300.*

Waldman H. and A. V. daRosa, 1971, "Prognostication of the Ionospheric Electron Content," *Technical Report SU-SEL-71-046* (SAMSO-TR-71-82).

Walker A. D., 1966, "The Theory of Guiding of Radio Waves in the Exosphere," *J. Atm. Terr. Phys.* 28 1039.

Walker W. F., 1966, "A Simple Baseband Fading Multipath Channel Simulator," *Radio Sci.* 1 7 763-767.

Wand I.C., T. B. Jones, 1970, "Full-Wave Studies of the Ionospheric Reflection Coefficients of VLF and LF Radio Waves," *J. Atmos. Terrest. Phys.* 32 5 737-56.

Wand R. H. and J. V. Evans, 1975, "Morphology of Ionospheric Scintillation in the Auroral Zone," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO, Washington, D.C.

Wand R. H. and J. V. Evans, 1975, Morphology of Ionospheric Scintillation in the Auroral Zone," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), NTIS CSCL 04/1 N74-30714.

Watkins B. J., 1978, "Numerical Computer Investigation of the Polar F-Region Ionosphere," *PLanetary and Space Science* 26(6) 559-569.

Watterson C. C., G. C. Ax, L. J. Dremmer and C. H. Johnson, 1969, "An Ionospheric Channel Simulator," *Tech. Memo. ERL TM-ITS 198.*

Watterson C. C., J. R. Juroshek and W. D. Bensema, 1970, "Experimental Confirmation of an HF Channel Model," *IEEE Trans. Comm. Tech.* 18 791.

Watterson C. C., J. R. Juroshek and W. D. Bensema, 1969, "Experimental Verification of an Ionospheric Channel Model," *Tech. Rep. ERL 112-ITS 80.*

Waylan J. A. and J. R. Sharber, 1981, "The Nighttime Auroral E Layer, Particle Production, Latitudinal and Longitudinal Structure and Dynamics," in *Effect of the Ionosphere on Radiowave Systems*, edited by J. M. Goodman, F. D. Clarke and J. Aarons, U.S. GPO, Washington, D.C.

Wernik A. W., C. H. Liu and K. C. Yeh, 1980, "Model Computations of Radio Wave Scintillation Caused by Equatorial Ionospheric Bubbles," *Radio Sci.* 15 559.

Whitehead J. D., 1970, "Production and Prediction of Sporadic E.," *Rev. Geophys. Space Phys.* 8 65.

Wildman P. J. L., R. C. Sagalyn and M. Ahmed, 1976, "Structure and Morphology of the Main Plasma Trough in the Topside Ionosphere," *Proc. COSPAR Sym. Geophys. Use of Sat. Beacon Obs.*, M. Mendillo (editor), Boston University, Boston, Ma.

Wilkins A. F., 1960, "HF Propagation—Its Present and Future Use for Communications Purposes," *J. Brit. Inst. Radio Engrs* 20 939.

Williams D. J., 1976, "SELDADS: An Operational Real-Time Solar Terrestrial Environment Monitoring System," *NOAA Technical Report ERL-357-SEL37.*

Williams H. P., 1962, "Increase in MUF Due to Horizontal Gradients, *Nature* 196 256.

Wong M. S., 1970, "Forecasting HF Absorption During Polar Cap Absorption Events," *Proceedings of Conference on Ionospheric Forecasting* 1.

Wright R. W. H., 1959, "Geomorphology of Spread-F and Characteristics of Equatorial Spread-F," *J. Geophys. Res.* 64 2203-2207.

Yakovski N, D. Fel'ske and R. Detman, 1979, "Morning Photoionization in Calculating Electron Content by Means of a Single-Ion Model of the Upper Ionosphere," *Geomagnetism and Aeronomy* 19(6) 1110-1112.

Yang C. C. and K. C. Yeh, 1981, "Temporal Behavior of Pulses after Propagation Through a Turbulent Ionosphere," in *Effect of the Ionosphere on Radiowave Systems*, J. M. Goodman (editor-in-chief), U.S. GPO, Washington, D.C.

Yeh K. C. and C. H. Liu, 1981, "Simulated Propagation Effects on Trans-Ionospheric Radio Waves," in *Effect of the Ionosphere on Radiowave Systems*, J. M. Goodman (editor-in-chief), U.S. GPO Washington, D.C.

Yeh K. C. and C. H. Liu, 1979, "Ionospheric Effects on Radio Communication and Ranging Pulses," *IEEE Trans. Antennas Propagat. AP-27* 747.

Yeh K. C., C. H. Liu and A. L. Hearn, 1979c, "Propagation of Gravity Wave Spectra in the Thermosphere," *J. Geophys. Res.* 84 834.

Yip K. W., F. B. Winn, M. S. Reid, and C. T. Stelzried, 1975, "Decimeter Modeling of the Ionospheric Columnar Total Electron Content at S-Band Frequencies," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO Washington, D.C.

Young E. R., D. G. Torr, P. Richards and A. F. Nagy, 1980, "A Computer Simulation of the Mid-Latitude Plasmasphere and Ionosphere," *Planet Space Sci.* 28 881.

Zacharisen D. H., S. M. Ostrow and G. C. Huang, 1969, "Validity of Revision Factors in Updating Long-Term F2-Layer Maximum Usable Frequency Predictions," *Technical Memorandum ERLTM-ITS 156* 13.

Zevakina R. A. and E. V. Lavrova, 1979, "On the Possibility to Predict Variations in the F2-Region Parameters as a Function of the IMF Direction," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO Washington, D.C.

Zevakina R. A. and M. V. Kiseleva, 1979, "On the Short-Term Prediction of the Space-Time Distribution of Auroral Absorption," in *Solar-Terrestrial Predictive Proceedings*, R. Donnelly (editor), U.S. GPO Washington, DC.

Zevakina R. A., Y. V. Lavrova and L. N. Liakhova, 1967, "Principles for Predicting Ionospheric and Magnetic Disturbances and Short Range Radio Services," Nauka, Moscow.

Zhulina E. M., E. M. Kovalevskaya and L. M. Ishkova, 1978, "Effect of Statistical Properties and Disturbances of the Ionosphere on Characteristics of Radio Wave Propagation," Geomagn. i. Aeron. 18 1057.

Zhulina E. M., T. S. Kerblaĭ, E. M. Kovalevskaya, and co-workers, 1969, "Fundamentals of Long-Term Radio Forecasting," Nauka, Moscow.

Ziemer R. E. and W. F. Deckelman, 1975, "Computer Simulation of Transionospheric Scintillation Communication Channels Based on Fade Duration Statistics," in *Effect of the Ionosphere on Space Systems and Communications*, J. M. Goodman (editor), U.S. GPO Washington, D.C.

Zimmerman M. S. and J. H. Horowitz, 1967, "A Flexible Transmission Channel Simulator," *Dig. 1967 IEEE Int. Conf. Communication*, Minneapolis, Minn., p. 73.

APPENDIX B

IONOSPHERIC MODEL AND MODEL USER QUESTIONAIRES

A. ORIGINATOR DATA

NAME ☐ DR. ☐ MR. ☐ MRS. ☐ MS. ___ OTHER ___ SURNAME ___ FIRST ___ MID. INIT.

TITLE & MAIL CODE ___

AFFILIATION ___ TELEPHONE ( ) ___ AREA CODE

ADDRESS ___

B. DOCUMENTATION
Below please list all documented needs of your organization related to ionospheric or ionospheric effects characterization which are expressed in terms of "operational requirements", "statements of need", or kindred documents.

1. ___

2. ___

3. ___

4. ___

5. ___

(Use Reverse Side for Continuation)

C. UNOFFICIAL NEEDS
Below please list all perceived needs of your organization related to ionospheric characterization. Such characterization needs should not exclude the assessment/forecasting/prediction of system effects.

___

(Use Reverse Side for Continuation)

D. Briefly indicate how knowledge of the ionosphere would be/is utilized in your programs. Are these needs being adequately addressed at present?

___

(Use Reverse Side for Continuation)

E. General:
O I would be willing to provide further information concerning current and planned future utilization of model(s). ☐ YES ☐ NO ☐ NOT APPLICABLE

O Additional information is requested. ☐ Telephone ☐ Letter ☐ Visit

Signed: ___

Please forward this questionaire to: Dr. John M. Goodman
NRL Code 4180
Naval Research Laboratory
Washington, D. C. 20375
Phone (202) 767-3729

IONOSPHERIC/PROPAGATION MODEL INFORMATION SHEET

RESPONSE VITAE

NAME: ☐ PROF. ☐ DR. ☐ MR. ☐ MRS. ☐ MS. ____ OTHER ____ LAST ____ FIRST ____ M.I.

ADDRESS: ______________________________
ORGANIZATION

____
STREET ADDRESS

____
CITY STATE ZIP CODE

____
COUNTRY

TELEPHONE: ______________ TELEX: ______________

1. NAME OF MODEL: ______________________________

2. AUTHOR (Custodian) OF MODEL: ______________________________

3. TYPE OF MODEL: ☐ PHYSICAL ☐ EMPIRICAL ☐ HYBRID
(Check appropriate box)

4. BRIEF ABSTRACT:

____
____
____
____
____
____
____
____
____
____
____
____
____
____
____

5. ASSUMPTIONS: ______________________________

6. PARAMETERS:

INPUT	OUTPUT

7. REFERENCE: (Articles/Reports/etc.)

8. APPLICABILITY/LIMITATIONS:

Diurnal ______________________________

Seasonal ______________________________

Solar Epochal ______________________________

Geographical ______________________________

Altitude ______________________________

Magnetic Activity ______________________________

Other Geophysical ______________________________

System Relevance ______________________________

9. HAS MODEL BEEN TESTED AGAINST: ________ Other Models? ________ Data? ________ Other?

10. IF "OTHER" EXPLAIN: ______________________________

11. RESULTS OF TEST: (accuracy/consistency/etc.)

12.

12.1 COMPUTER	12.2 INFORMATION	12.3 IMPLEMENTATION
Computer (Make,Model)	Language(s)	Program Speed (Running time) typical)
A.		
B.		
C.		
D.		

12.4 I/O DEVICES REQUIRED:

	A	B	C	D
Tape Systems				
Terminals				
Printers				
Card Readers				
Teletype				
Plotter				
Other				

12.5. STORAGE DEVICES REQUIRED:

Core				
Tape				
Disk				
Other				

12.6 OPERATING SYSTEM REQUIRED:

12.7 EXECUTION MODES:

Batch

Interactive

13. IS THIS MODEL CONSIDERED CURRENT? ☐ Yes ☐ No

14. WHAT CHANGES/IMPROVEMENTS ARE ENVISIONED? SUGGESTED?

15. IS THE MODEL CAPABLE OF UPDATE USING REAL-TIME DATA? ☐ YES ☐ NO

16. HOW WOULD THIS BE ACCOMPLISHED?

17. GENERAL REMARKS:

*U.S. GOVERNMENT PRINTING OFFICE: 1982 361-334/532 1-3

END

DATE
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